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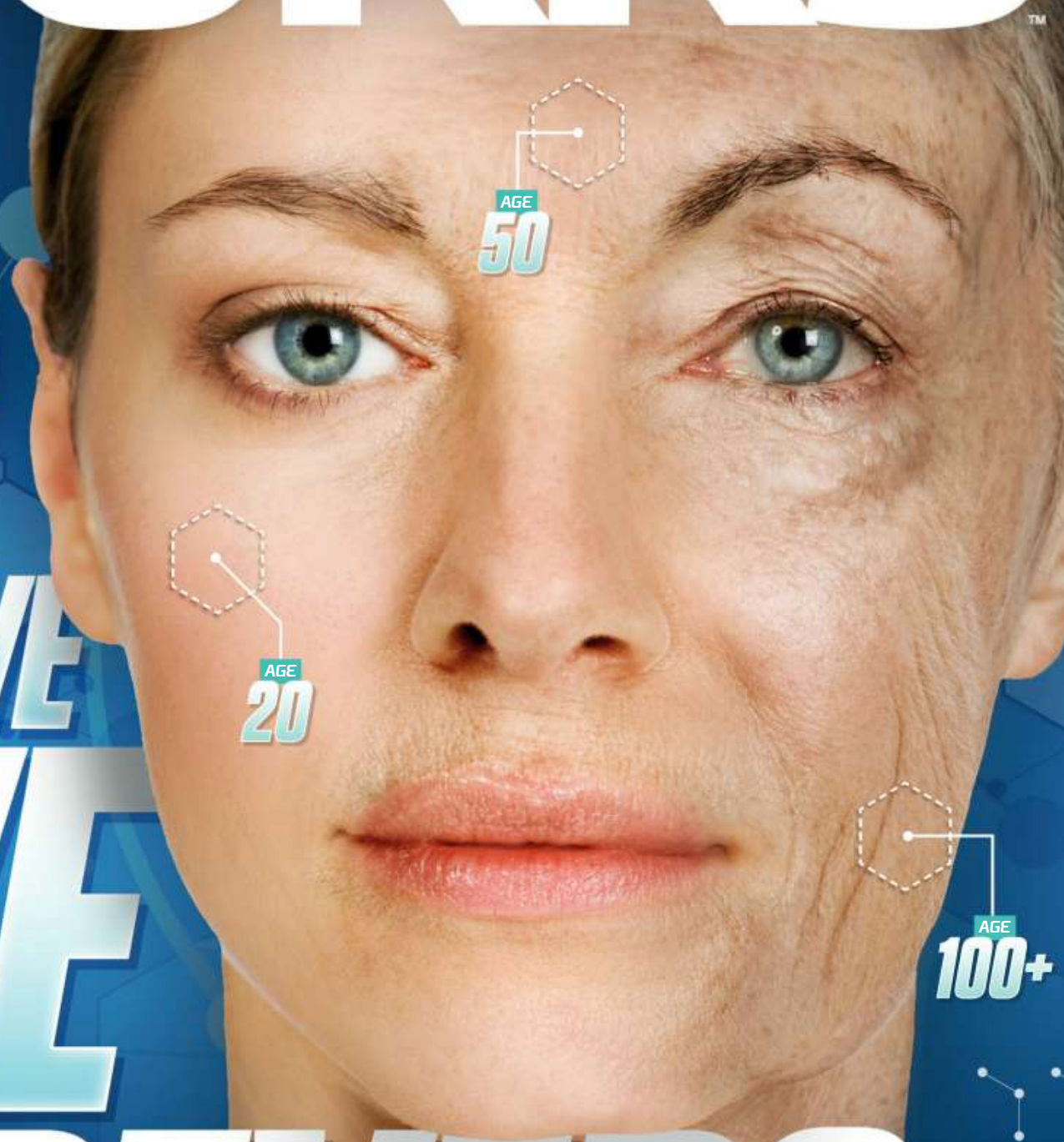

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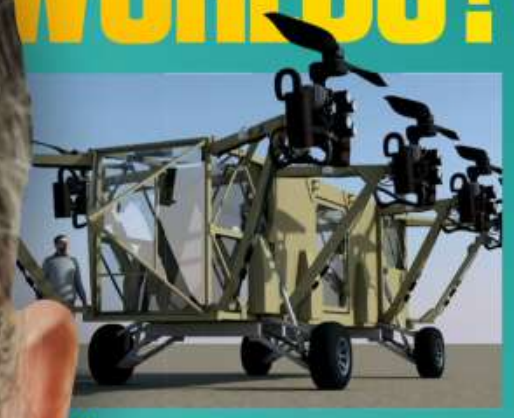

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WELCOME

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"It would involve uploading your consciousness into a computer"

Can we live forever? Page 26

The red X-shaped object in the image above is a chromosome, a DNA molecule that contains some or all of the genetic material in your body. The little blue caps on the ends of it are telomeres, which protect the molecule, but also play a huge role in the ageing process. Those tiny parts of our genetic make-up dictate an enormous part of our lives, our quality of life and how many years we can expect to live. In this issue of **How It Works**, we explore the ageing process and what's happening in your body from the moment you were born right across every stage of your life. We also look at some of the technologies scientists are exploring that could extend human life in the future. Enjoy the issue!

Ben Editor

Meet the team...

Nikole
Production Editor
On page 48, dive down into the depths to explore some of the cities of the past that now lie beneath the briny blue, frozen in time.

Scott
Staff Writer
Oil is a precious natural resource, as it has a multitude of uses. Find out how we refine and use this fossil fuel on page 36.

Baljeet
Research Editor
As far as we know, life is unique to Earth. But how did it get here in the first place? On page 42, we explain one popular theory.

Duncan
Senior Art Editor
Smart glasses are becoming widely adopted in many industries as a design and education tool. Learn more on page 56.

Ailsa
Staff Writer
You hear the buzz of bees and wasps during summer, but where do they hide year-round? Peek inside their homes on page 76.

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CAN WE LIVE FOREVER?

AR ZONE!

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MEET THIS ISSUE'S EXPERTS...

Lauren Eyles
Marine biologist and PADI dive master Lauren has been leading the fight against plastic pollution for over ten years. She's appeared on *BBC Coast*, *Springwatch* and other wildlife programmes.

Andy Extance
Andy is a freelance science writer based in Exeter, UK. He previously worked in early stage drug discovery research, followed by a brief stint in silicone adhesive and rubber manufacturing.

Dr Andrew May
Andrew has a PhD in astrophysics and 30 years in public and private industry. He enjoys space writing and is the author of several books.

Mark Smith
A technology and multimedia specialist, Mark has written tech articles for leading online and print publications for many years.

Jo Elphick
Jo is an academic lawyer and lecturer specialising in criminal law and forensics. She is also the author of a number of true crime books.

Amy Grisdale
Volunteer animal worker Amy has an enormous breadth of experience on animal conservation projects. She specialises in writing about environmental topics.

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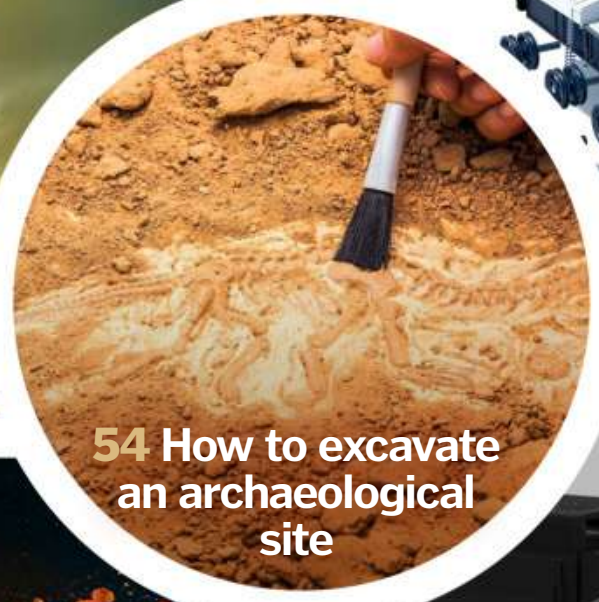

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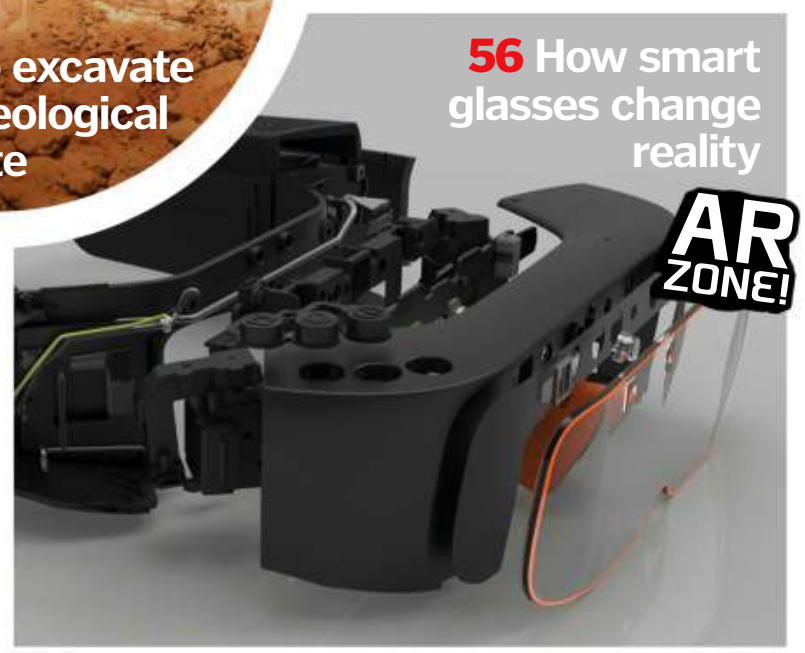

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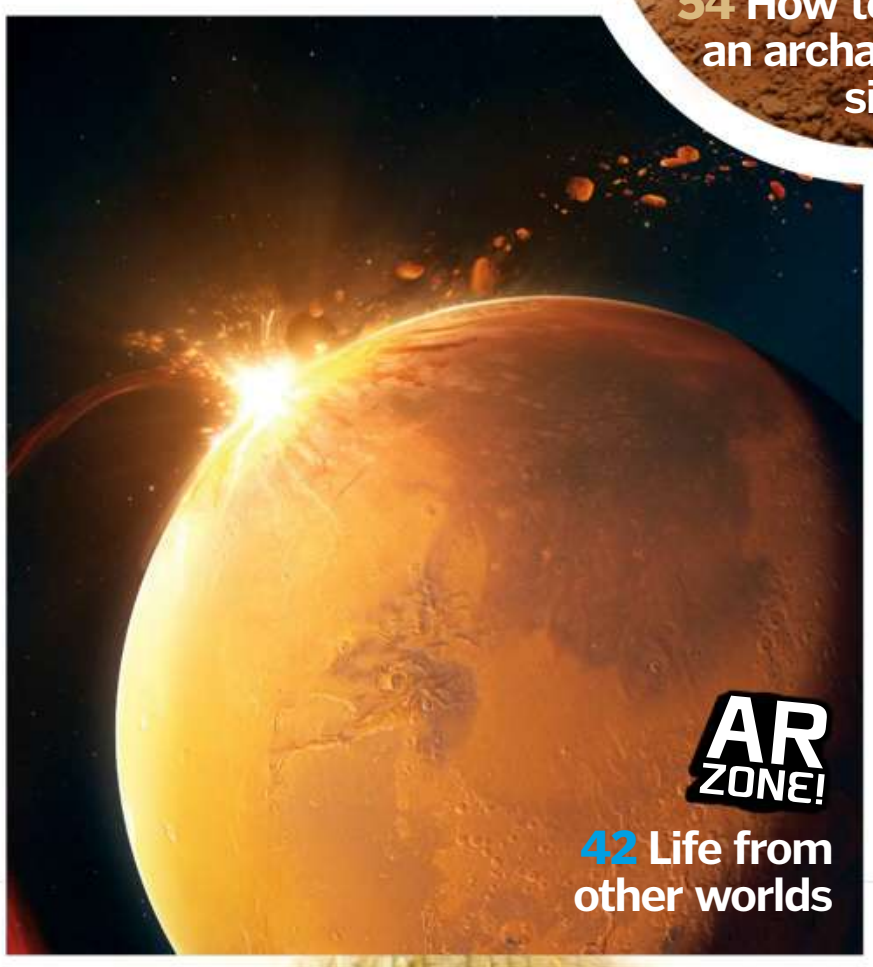

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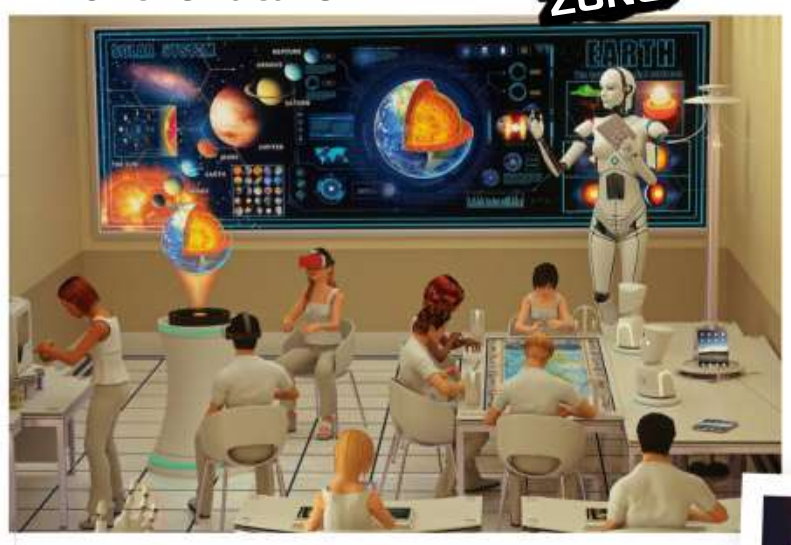

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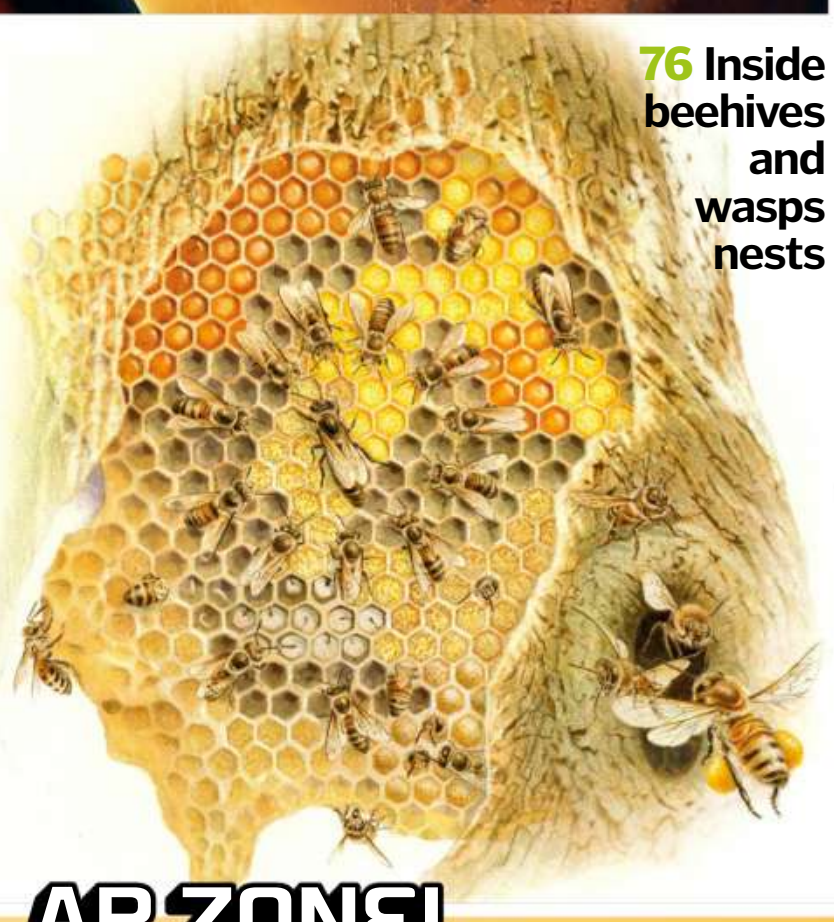

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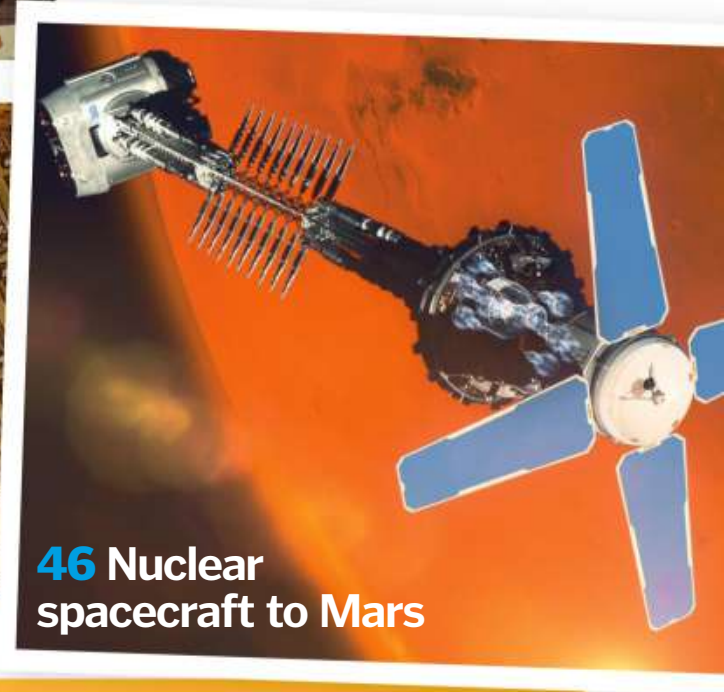

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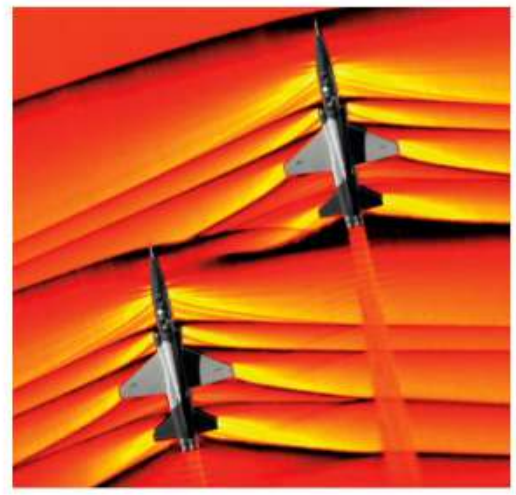

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Hold your mobile device over the image and watch it come to life! Your device needs to be connected to the internet for this to work

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After being launched by the QR code, the app reads anything you point your device's camera at 30 times a second, searching for distinctive shapes we've trained it to recognise. When it sees a familiar picture, it overlays the augmented-reality 3D image we've previously uploaded on your screen.

MILLIPEDE UNDER THE MICROSCOPE

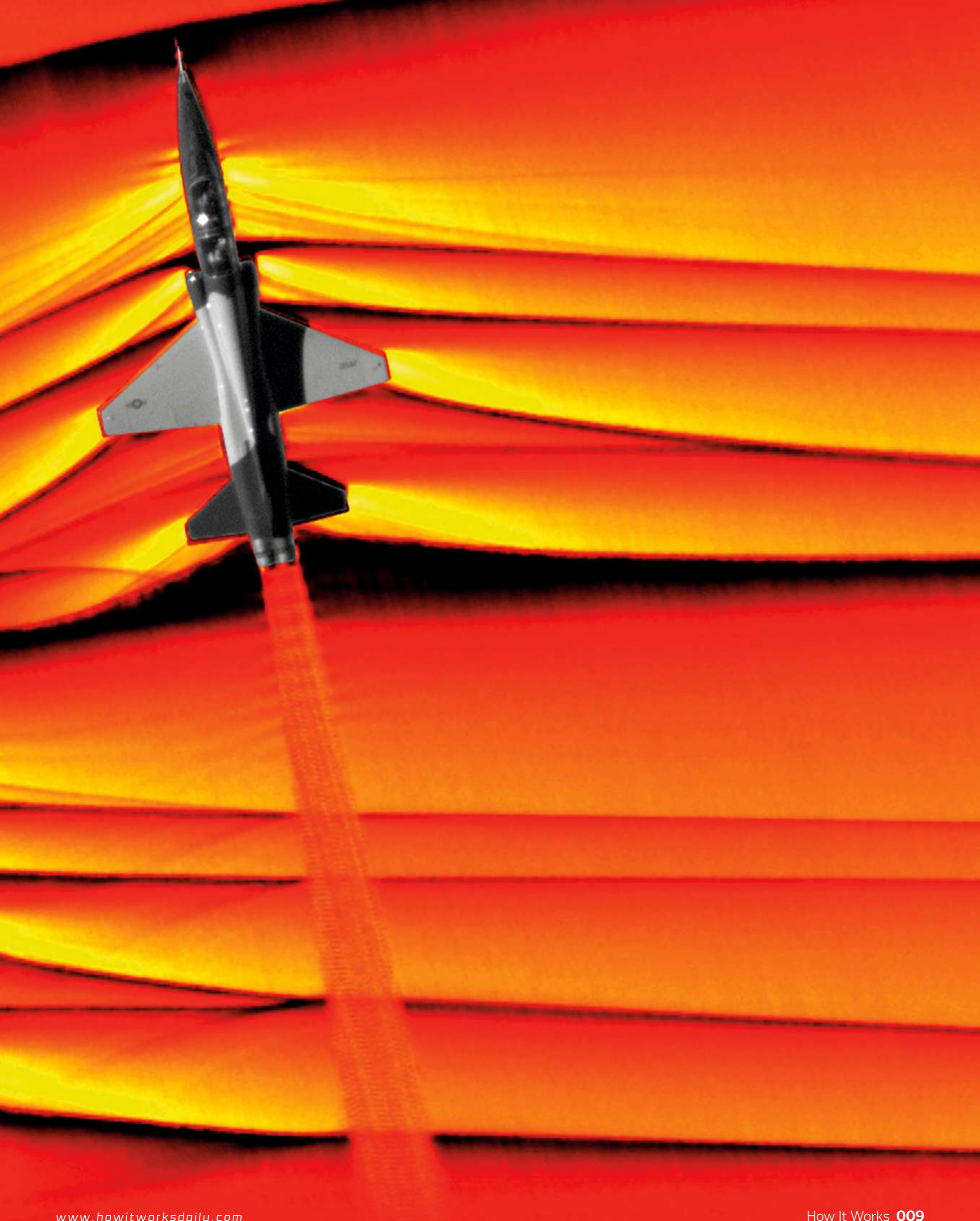
This is a coloured scanning electron microscope image of a male millipede (Diplopoda). There are around 10,000 species of millipede worldwide, including 50 species in Britain. Millipedes use their antennae to navigate by tapping the ground. They're also coated with hair-like cells that detect odours as part of the insects' olfactory system. This helps them to 'sniff' out food, such as decomposing plants or fungi. Millipedes also come equipped with a group of hairs on the second or third pair of their legs that they use to brush and clean their antennae.

© Getty

SEEING SUPERSONIC

NASA captured this image of the shock waves from two US Air Force Test Pilot School T-38 aircraft flying around nine metres away from one another back in 2019. Both supersonic planes were travelling past the speed of sound and produced deafening 'supersonic boom' shock waves, shown as the dark lines. The image was originally monochromatic – taken using the Schlieren photography technique, which can visualise the flow of air from the surface of an object – then colourised. Highlighting the waves in this way helps researchers to understand how shock waves interact with aircraft and other shock waves.

© NASA



MADRID SNOWSCAPE

At a glance this photo looks like it has been taken in monochrome. However, it's in full colour. On 11 January 2021, Madrid, Spain's capital, was hit by Storm Filomena, dumping more snow on the city than has been seen in the last 50 years. The image was captured by the Copernicus Sentinel-2 mission, which comprises two identical polar-orbiting satellites that cover all Earth's land surfaces at the equator every five days. Each of the satellites carry high-resolution cameras that can collect data from a strip of land 180 miles wide at one time. This helps researchers monitor changes on Earth's surface.

© Getty

POLLEN PILE

Shoeblackplant (*Hibiscus rosa-sinensis*) – also colloquially called the 'Rose of China', 'Hawaiian hibiscus' and 'rose mallow' – produces thousands upon thousands of pollen grains in a single pinch of pollen powder. Pollen grains, seen here in purple, are the male reproductive cells of a plant. They form with a spiky, tough outer shell called the exine. This prickly casing allows the pollen grains to easily attach to the bodies of insect pollinators and survive the journey to another plant. If the pollen grain is successfully dispersed, it will fertilise the female reproductive cells in another plant's ovules. Each of these grains is around 15 to 100 microns wide, snapped using a coloured scanning electron microscope.

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With over 14 million global monthly users, **Live Science** makes every day a little more interesting by illuminating the fascinating world around us. For the science geek in everyone, **Live Science** breaks down the stories behind the most interesting news and photos on the internet.

The black hole Cygnus X-1 is pulling in material from a massive blue companion star

© Getty

SPACE

Fastest spinning black hole in the cosmos discovered

Words by **Tim Childers**

Six decades after its discovery, the first black hole ever detected is still causing astronomers to scratch their heads. It turns out that the cosmic behemoth at the heart of the Cygnus X-1 system is 50 per cent more massive than previously thought, making it the heaviest stellar-mass black hole ever observed directly.

Based on new observations, an international team of researchers estimates the black hole is 21 times the mass of our Sun and spinning faster than any other known black hole. The recalculated weight is causing scientists to rethink how bright stars that turn into black holes evolve and how fast they shed their skins before they die.

The mass of a black hole depends on the properties of its parent star, such as the star's mass and its metallicity – how much of it is made up of elements heavier than helium. Over a star's lifetime, it sheds its outer layers through blasts of stellar wind. Bigger stars rich in heavy elements shed their mass faster than smaller stars with less metallicity.

"Stars lose mass to their surrounding environment through stellar winds that blow away from their surface. But to make a black hole this heavy and rotating so quickly, we need to dial down the amount of mass that bright stars lose during their lifetimes," said Ilya Mandel, an astrophysicist from Australia's Monash University.

Researchers estimated the mass of Cygnus X-1 using a tried-and-tested method of measuring the distances of stars from Earth, called parallax. As Earth orbits the Sun, astronomers measure the visible movement of stars relative to the background of more distant stars, and with a bit of trigonometry they can use that movement to calculate the star's distance from Earth.

In addition, Cygnus X-1's black hole is slowly devouring its bright-blue companion star by sucking in that star's outer layers, forming a bright disc rotating around the black hole. As the matter falls into the black hole, it gets heated to millions of degrees and emits X-ray radiation. Some of this matter narrowly escapes the black hole and is spit out in powerful jets, emitting radio waves detectable on Earth.

It was these signature bright jets that the research team tracked, using observations from the Very Long Baseline Array (VLBA), a

continent-sized network of ten radio telescopes spread across the US, stretching from Hawaii to the Virgin Islands. Over a period of six days, they followed the black hole's full orbit around its companion star and determined how much the black hole shifted in space.

They found that Cygnus X-1 is around 7,200 light years from Earth, surpassing the previous estimate of 6,000 light years. The updated distance suggests the blue supergiant companion star is brighter and more massive than previously thought, at 40-times more massive than our Sun. Given the orbital period of the black hole, they were able to give a new estimate for the black hole's mass, a whopping 21 solar masses.

"Using the updated measurements for the black hole's mass and its distance away from Earth, we were able to confirm that Cygnus X-1 is spinning incredibly quickly, very close to the speed of light and faster than any other black hole found to date," said Lijun Gou, a researcher at the National Astronomical Observatories of the Chinese Academy of Sciences (NAOC).

Elizabeth Ann at 68 days old, the first cloned black-footed ferret and first-ever cloned US endangered species

© USFWS National Black-footed Ferret Conservation Center

ANIMALS

Endangered ferret cloned for the first time

Words by **Rachael Rettner**

Researchers have successfully cloned a highly endangered ferret species using cells that were frozen more than three decades ago. The adorable clone, named Elizabeth Ann, is a species of black-footed ferret, one of the most endangered mammals in North America. Born on 10 December 2020, Elizabeth Ann was created using cells from Willa, a wild black-footed ferret who died and had her cells cryopreserved in 1988.

The feat marks the very first time an endangered species in the US has been cloned. Researchers hope Elizabeth Ann will help to bring genetic diversity to the black-footed ferret population, which today is descended from just seven individual ferrets, making all living members of the species essentially half-siblings.

"It was a commitment to seeing this species survive that has led to the successful birth of Elizabeth Ann," said Ryan Phelan, executive director of Revive & Restore, a conservation organisation that was involved with the cloning. "To see her now thriving ushers in a new era for her species and for conservation-dependent species everywhere. She is a win for biodiversity and for genetic rescue."

Black-footed ferrets were once thought to be extinct, but scientists found a small population in 1981, which allowed conservationists to start captive breeding programs for the species. About 250 to 350 of the ferrets live in captivity, and 300 more live in reintroduction sites in the wild. However, the limited genetic diversity of the species has challenged its recovery, making the creatures prone to health disorders and certain infections. Since Willa was not one of the 'seven founders' of the population, her genes, which are now possessed by Elizabeth Ann, could bring much-needed variation to the population's genetics.

The project to clone a black-footed ferret began in 2013, the result of a partnership between the US Fish and Wildlife Service, Revive & Restore, the company ViaGen Pets & Equine, San Diego Zoo Global and the Association of Zoos and Aquariums. Several other endangered animals have been cloned in other parts of the world, including gaur, or wild cattle, in 2001; bucardo, or wild goats, in 2009 and wild coyotes in 2012.

"To see her now thriving ushers in a new era for her species and for conservation-dependent species"

HEALTH

DNA found twisting into weird shapes to get into cells

Words by **Yasemin Saplakoglu**

Scientists recently captured a high-resolution video of DNA shimmying into weird shapes in order to squeeze inside cells. In 1952 Rosalind Franklin produced the first indirect picture of DNA by studying how X-rays bounce off these fundamental molecules. But it wasn't until 2012 that scientists captured a direct photo of DNA using an electron microscope.

Now a group of researchers in the UK have captured high-definition videos of DNA in motion using a combination of advanced microscopy and simulations. But they weren't just playing paparazzi to the building blocks of life; they were trying to understand how DNA moves to squeeze itself into cells.

Human cells contain about two metres of DNA. Considering human cells are on the order of micrometres, DNA has to be really good at 'supercoiling', or bending and folding itself to tightly pack inside the cell. But until recently technology wasn't good enough for scientists to clearly see what the DNA structure looked like as it supercoiled. The researchers looked to 'DNA minicircles' isolated and engineered from bacteria. These circular DNA structures are also found in human cells, and their function is largely unknown. The researchers used these ring structures because scientists can twist them in a way that wouldn't have worked with long strands, DNA's most common form.

To see the movement in detail, the researchers used a combination of supercomputer simulations and atomic force microscopy – in which a sharp tip glides across the surface of the molecule and measures the forces pushing back on the tip to outline the structure. "Seeing is believing, but with something as small as DNA, seeing the helical structure of the entire DNA molecule was extremely challenging," said Alice Pyne, a lecturer in polymers and soft matter at the University of Sheffield. "The videos we have developed enable us to observe DNA twisting in a level of detail that has never been seen before."

The microscope images were so detailed that the researchers could see the double-helix structure of the DNA. After they combined these images with simulations, they could see the position of every single atom in the DNA as it moved.

Interestingly, DNA in its relaxed form barely moved. But when twisted, as it normally does when squeezing into a cell, the DNA morphed into many other shapes. These various shapes influenced how the DNA molecule interacted with and bound to other DNA molecules around it.

Lynn Zechiedrich, a professor at the Baylor College of Medicine in Houston, Texas, who provided the minicircles for the study, discovered how to use these ring structures as vectors for gene therapy by inserting small genetic messages into the rings.

The study researchers "have developed a technique that reveals in remarkable detail how wrinkled, bubbled, kinked, denatured and strangely shaped they are," said Zechiedrich, who wasn't directly involved in the study. "We have to understand how supercoiling, which is so important for DNA activities in cells, affects DNA in hope that we can learn how to mimic or control it."

DNA's strange shimmying was captured using microscopy

© University of Leeds

These views of the restored copper statue show its fashionable hairstyle

© National Trust/Oxford Archaeology East/James Fairbairn

HISTORY

Ancient deity statue wears a mullet and moustache

Words by **Mindy Weisberger**

A tiny statue of a Celtic deity dating to the Iron Age wears a haircut that was widespread – and widely mocked – decades ago, but is now enjoying an unexpected comeback: the mullet. Worn with the hair cut short in front and long at the back of the head, mullets surged in popularity during the 1980s. Archaeologists recently discovered the same hairstyle on a copper figure measuring about five centimetres tall, found at an Iron Age site in Cambridgeshire, England, and dating to the first century CE.

Like countless football players, hockey stars, rock musicians and partygoers that came thousands of years later, the statue's hair is cropped close to its head around the crown and flows long down its back. Also resembling many male mullet-wearers from the 1980s, the statue sports a tiny moustache.

In 2018 archaeologists began excavating a site at Cambridgeshire's Wimpole Estate, uncovering a rural settlement spanning several centuries – from the late Iron Age, beginning around the first century BCE, to the early Roman period. In addition to the statue they found about 300 metal objects, including fittings from a Roman military uniform, cosmetic tools, coins and nails and fittings for horse harnesses.

Though researchers initially thought that the small statue represented Cernunnos, the Celtic god of fertility, they later determined it was another unknown deity. The figure likely served as a handle for a spatula that mixed wax or medicines. Its hands clasp a torc – a circular ornament worn around the neck – that may have once held a decorative inlay.

"This figure is an exceptional find, and thanks to careful conservation and cleaning we can now see some remarkable detail," said Shannon Hogan, a National Trust archaeologist for the east of England.

However, it's unknown whether the deity's impressive mullet was meant to represent the overall popularity of the haircut in the region at that time, or if that was how the god's hair was typically styled in statues and other art.

SPACE

'Spider star' gamma-ray mystery solved

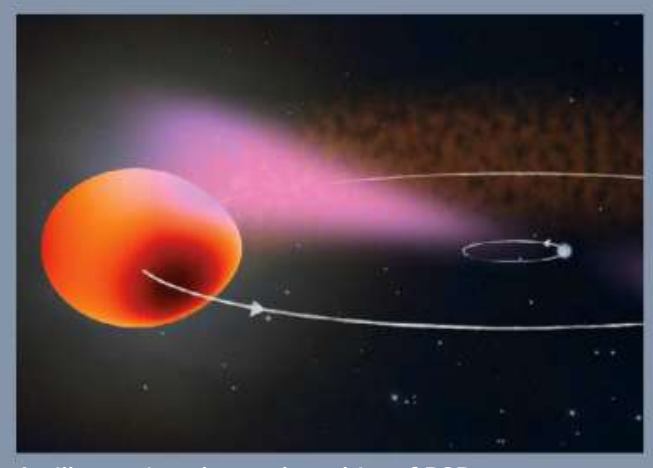
Words by **Rafi Letzter**

The mystery at the heart of an unexplained bright point of gamma-ray light in the sky has been solved: there's a deadly spider star flaying a second star to bits, sending out rapid-fire bursts of gamma radiation in the process.

'Black widows' and 'redbacks' are types of neutron stars, the ultradense remnant cores of giant stars that exploded. Some neutron stars, called pulsars, rotate at regular intervals, flashing like lighthouses. The fastest spinning are millisecond pulsars. When a millisecond pulsar is locked in a rare tight orbit with a lightweight star, it slowly shreds its partner to bits with each rotation. These binary cannibals are known as black widow or redback stars.

Since its discovery in 2014, researchers have suspected that PSR J2039–5617 contained a millisecond pulsar and a second star. The bright source of X-rays, gamma rays and visible light closely matched the expected traits of such a system. But proving it required scads of telescope data and more number-crunching than a typical desktop computer could do in a century.

To prove that the star system was indeed a redback, the researchers leaned on the computing power of Einstein@Home, a project of the LIGO Scientific Collaboration and Germany's Max Planck Institute where more than 500,000 volunteers let their idle computers work together on complex astronomy problems.



An illustration shows the orbits of PSR J2039-5617 and its companion

© B. Knispel / C.J. Clark / Max Planck Institute for Gravitational Physics / NASA's Goddard Space Flight Center

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ANIMALS

Humpback survives orca attack

Words by **Stephanie Pappas**

Whale watchers in Australia witnessed a rare sight last month when two pods of orcas ganged up on and attacked a healthy young humpback whale. The humpback, a two- to three-year-old male, survived the onslaught, though he lost his dorsal fin. "We knew we were witnessing something significant," said Gemma Sharp, the co-owner of Whale Watcher Australia, who was present during the attack on 17 February. "The orca were in full-on attack mode, and the humpback was desperately trying to protect itself."

Sharp and a boat full of whale watchers were in Bremer Bay in Western Australia when they spotted about 15 orcas splashing at the surface. They soon realised the predators were surrounding a humpback whale (*Megaptera novaeangliae*). As the humans watched, the orcas tried again and again to grab the humpback's dorsal fin to flip the whale over and drown it.

The flip-and-drown tactic often works on whale calves and yearlings, but the young male was too strong and large for the orcas to budge him. The whale made a beeline towards the boat, taking cover underneath it for almost an hour.

As the orcas circled, hoping for another chance, the commotion attracted a group of 50 pilot whales and a group of bull sharks. Eventually one of the orca pods left. Another pod of six orcas waited about 300 metres away from the boat until the humpback decided to make a break for it.

© Whale Watch Western Australia

This humpback whale survived a four-hour-long attack by pods of orcas

It looks like Jupiter kicked the asteroid down to Earth

© Getty

PLANET EARTH

Dinosaur-killing rock came from the edge of the Solar System

Words by **Stephanie Pappas**

The chunk of space rock that killed the non-avian dinosaurs may have been a piece of comet that Jupiter's gravity kicked onto a collision course with Earth. A new study suggests that the dinosaur-killing object was not an asteroid from between Jupiter and Mars, as is often hypothesised. Instead, the study authors argue, the impactor was a piece of comet from the Oort Cloud, a mass of icy bodies that surrounds the outer edges of the Solar System.

Long-period comets from the Oort Cloud take hundreds of years to make a lap around the Sun, and previous studies had suggested that their chances of crossing the path of a planet are too low to make them a likely culprit for the extinction of the non-avian dinosaurs – and 75 per cent of all other life on Earth – roughly 66 million years ago. But recent research has found that Jupiter's gravity pushes about 20 per cent of these long-period comets close to the Sun, where they break apart. The resulting fragments are ten-times more likely than other Oort Cloud comets to hit Earth.

The impact at the end of the Cretaceous Period left a crater about 93 miles in diameter near the present-day town of Chicxulub, Mexico, lending the guilty space rock its name: the Chicxulub impactor. The rock was at least six miles wide and hit the planet at about 44,640 miles per hour.

> "More objects in the Oort Cloud have this composition"

Where the Chicxulub impactor came from is a matter of debate. Geological analysis of the crater suggests that it was a carbonaceous chondrite, a type of meteor that makes up only about ten per cent of those found within the main asteroid belt in the Solar System. It's possible that more of the objects in the Oort Cloud have this composition.

Researchers have simulated the paths of long-period comets from the Oort Cloud past Jupiter and found that the gravitational field of the Solar System's largest planet turns about one-fifth of long-period comets into 'Sun-grazers', which are comets that pass very close to the Sun. At close range the Sun's gravity pulls harder on the close side than on the far side of this type of comet, creating tidal forces that can break the comet apart.

The fragments from these celestial break-ups are more likely than an intact comet to intersect with Earth on their return journey towards the Oort Cloud; such events are capable of producing a Chicxulub-size impact every 250 to 730 million years. "Our paper provides a basis for explaining the occurrence of this event," said Avi Loeb, an astronomer at Harvard University. "We are suggesting that if you break up an object as it comes close to the Sun, it could give rise to the appropriate event rate and also the kind of impact that killed the dinosaurs."

HISTORY

Experts trace hidden 'madman' message on *The Scream*

Words by **Yasemin Saplakoglu**

Written in tiny, faint letters in the top-left corner of Edvard Munch's painting *The Scream* is a mysterious inscription that reads: "Could only have been painted by a madman!" Experts have long debated the identity of the inscriber, with some suggesting a dissatisfied vandal is the author, while others pointed fingers at the Norwegian painter himself. Now a new analysis finds that the mysterious phrase was almost undoubtedly inscribed in Munch's own handwriting. The faint inscription, written in pencil, is visible to the naked eye, but it isn't very clear.

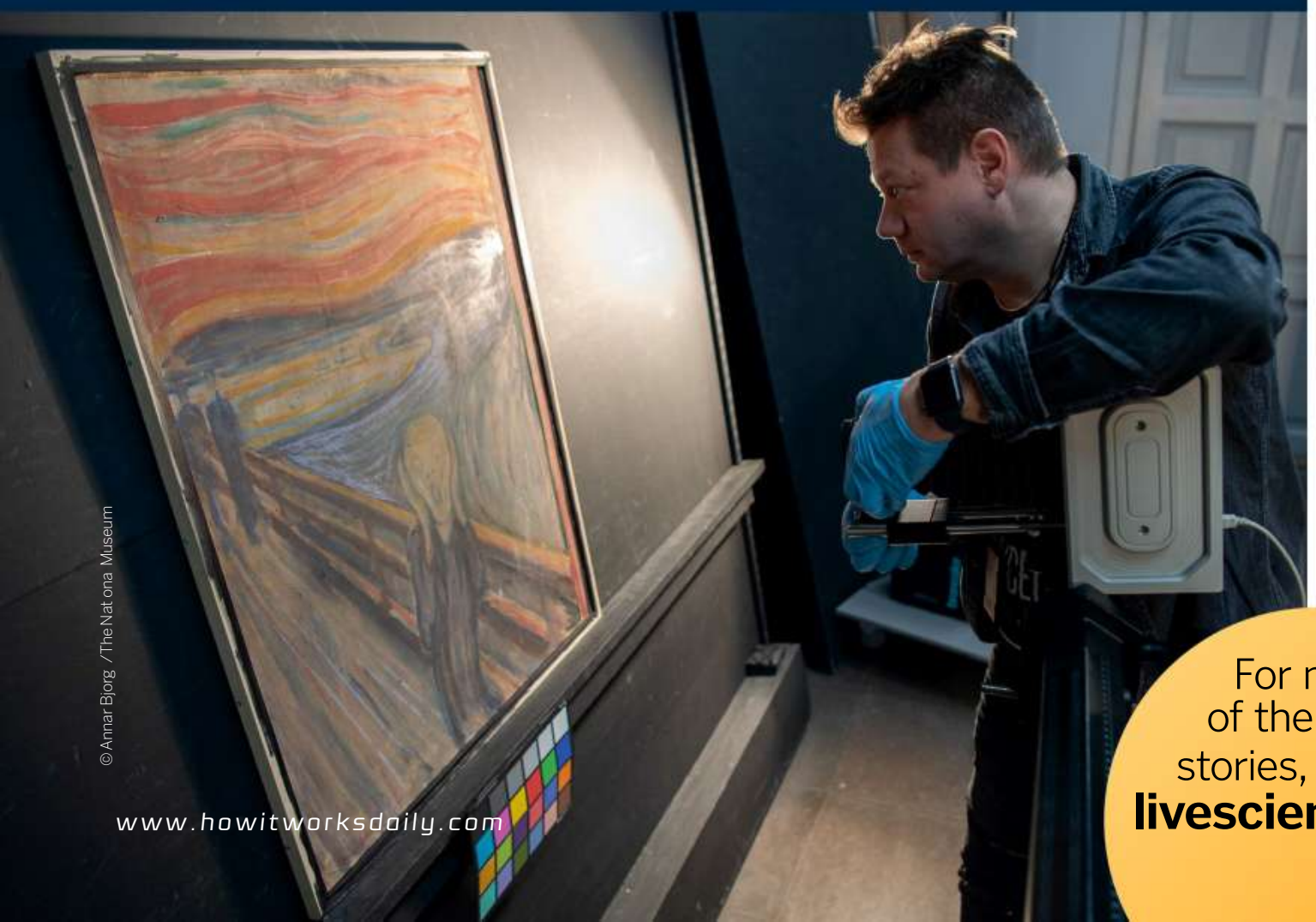
The inscription was first mentioned by a Danish art critic in 1904 when the painting was on exhibit in Copenhagen about 11 years after Munch painted it. At the time the critic thought that a member of the public wrote the message.

To understand the mystery, Mai Britt Guleng, the curator at the National Museum of Norway, and his team took infrared photos of the painting. The scans made the carbon from the pencil marks much clearer. The researchers compared the inscriptions with Munch's handwriting in his diaries and letters and analysed the details of the painting's first showing in Norway.

"The writing is without a doubt Munch's own," said Guleng. "The handwriting itself, as well as events that happened in 1895, when Munch showed the painting in Norway for the first time, all point in the same direction." The researchers hypothesise that Munch wrote this phrase after his painting was exhibited for the first time domestically at the Blomqvist Gallery in Norway in 1895. This exhibition in Norway drew much criticism, with one art critic Henrik Grosch writing that the painting is proof people should not "consider Munch a serious man with a normal brain".

At the time the Student Society in Kristiania, now Oslo, held a discussion event about his paintings, where some people expressed positive views about his art. But others, such as medical student Johan Scharffenberg, questioned Munch's mental state. Munch was likely there, and evidently took those comments to heart – he brought up the event in his letters and diary entries several times in the decades following."The theory is that Munch wrote this after hearing Scharffenberg's judgment on his mental health sometime in or after 1895. It is reasonable to assume that he did it quite soon after, either during or following the exhibition in Kristiania," Guleng said.

This version of *The Scream* was one of four versions painted by the artist, but the only one with such an inscription



© Annar Bjorg / The Nat ona Museum

© NASA / ISS

Mining pits glitter like gold in this aerial photo of the Peruvian Amazon

PLANET EARTH

'Rivers of gold' rush through the Amazon

Words by **Brandon Specktor**

The Peruvian Amazon glitters like gold in a gorgeous new photo taken aboard the International Space Station. While that glow is just sunlight reflecting off hundreds of pits of muddy water, there is plenty of gold in the hills. Each glistening pool is a gold-prospecting pit, likely dug by independent miners looking to unearth some of the Amazon's treasures.

"Each pit is surrounded by devegetated areas of muddy soil," Dr Murray Justin Wilkinson of Texas State University said. "These deforested tracts follow the courses of ancient rivers that deposited sediments, including gold."

Peru's Madre de Dios state is home to one of the largest independent gold-mining industries on Earth. As many as 30,000 small-scale miners prospect illegally in the area, working outside of government regulations and tearing up the Amazon rainforest with excavators and dump trucks in order to unearth the gold that may be hidden underneath.

Illegal mining can be a boon to impoverished workers in Madre de Dios, but is a detriment to the Amazon – gold mining is the single greatest cause of deforestation in the region.

These unregulated operations also pose a risk to local communities. Miners mix sediments with boiled mercury in order to separate gold from other minerals. As a result, up to 50 tonnes of mercury ends up in rivers or the atmosphere every year. Locals who eat a lot of fish from these polluted rivers are more than three times as likely to have mercury poisoning than people who don't consume fish.

But from space these harsh realities blur out of focus. For the astronaut who took this photo on 24 December 2020, the world far below was just a river of gold.

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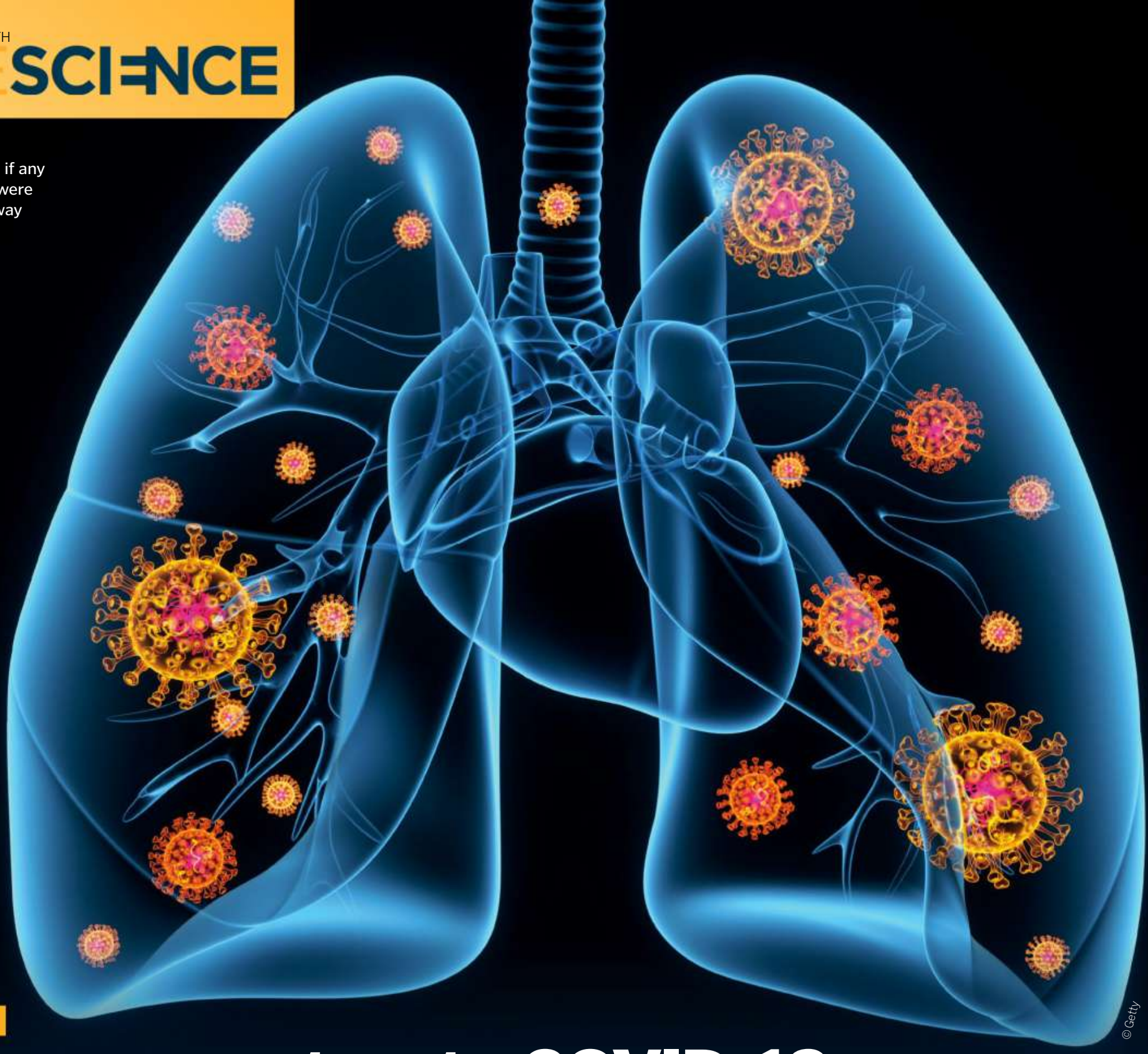
It's unknown if any other cases were spread this way



© Getty

HEALTH

Woman contracts COVID-19 from lung transplant

Words by **Rachael Rettner**

A lifesaving operation turned tragic when a Michigan woman contracted COVID-19 from her double lung transplant last year and died soon after. The case marks the first time that doctors have confirmed COVID-19 transmission through an organ transplant. A report of the unique case was published in the *American Journal of Transplantation*. A surgeon involved in the woman's case also contracted COVID-19, likely during the transplant procedure, and has now recovered.

Given that this is the only confirmed case spread through organ transplantation out of nearly 40,000 transplants performed in the US in 2020, transmission through this route is rare. But doctors involved with the case are calling for more extensive COVID-19 testing of lung donors to prevent such transmission from happening. In this case, the donor, who died in a car accident, was unknowingly infected with COVID-19 and tested negative on standard tests of the nose and throat. "We would absolutely not have used the lungs if we'd had a positive COVID test," Dr Daniel Kaul, director of Michigan Medicine's transplant infectious disease service, said.

The lung transplant recipient was a woman with chronic obstructive pulmonary disease (COPD). Her transplant procedure went smoothly, but just three days after the operation she developed a fever and breathing problems and was placed on a ventilator. Samples from her lungs tested positive for COVID-19. Though standard COVID-19 tests came back negative, doctors found a sample of fluid that had been washed through the donor's lungs. This lung fluid sample tested positive for COVID-19.

Genetic sequencing revealed that the coronavirus infecting the recipient and the donor were identical, confirming that the recipient contracted the virus from the donor's lungs. The surgeon, who showed symptoms four days after the transplant procedure, was also infected with a virtually identical virus, which he likely contracted from material expelled from the donor lungs during the operation.

After contracting COVID-19, the transplant recipient developed multi-organ failure and died two months later, despite extensive treatment. "Transplant centres and organ procurement organisations should perform SARS-CoV-2 testing of lower respiratory tract specimens [from deep in the lungs] from potential lung donors," the authors wrote in their case report. In addition, transplant centres should "consider enhanced personal protective equipment for healthcare workers involved in lung procurement and transplantation" such as N95 masks and eye protection, they concluded.

These carnivorous plants generate tiny magnetic signals when they clamp down on insects

© Getty

STRANGE NEWS

Venus flytraps produce magnetic fields

Words by **Yasemin Saplakoglu**

Carnivorous plants known as Venus flytraps (*Dionaea muscipula*) lure insects between their blushing leaves with a fragrant nectar. When these insect-hungry plants snap down on their unassuming prey, they generate a measurable magnetic field.

The plant's magnetic field is more than a million times weaker than Earth's. Rather than serving a function for the plant, this magnetic field is likely a by-product of electrical energy that flows through its leaves. Still, it's one of the first such fields ever detected in plants.

"Wherever there is electrical activity, there should also be magnetic activity," said Anne Fabricant, a doctoral candidate at Johannes Gutenberg University of Mainz and the Helmholtz Institute in Germany. The laws of electromagnetism dictate that anything with an electrical current also generates a magnetic field, including humans, animals and plants. However, not much has been done to understand biomagnetism in the plant world.

In a recent study, Fabricant and her team used tiny glass sensors called 'atomic magnetometers' containing a vapour of atoms that are highly sensitive to magnetic fields. They then triggered electrical energy – in the form of an action potential – to flow through the Venus flytrap. Action potentials, which also occur in animal and human nervous systems, are bursts of electrical energy that allow cells to communicate. Action potentials serve a vital function for the Venus flytrap, triggering the plant to close its leaves around insects that touch sensitive hairs on the plant's leaves.

But the researchers also stimulated the plant in another way, by using heat. They found that when stimulated, the Venus flytrap created a magnetic field up to a strength of 0.5 picotesla. That's similar to the levels generated by nerve impulses in animals. "It's exciting to demonstrate plant-biomagnetic measurements using atomic magnetometers, which operate at room temperature and can be portable and miniaturised," Fabricant said. "The fact that we were able to detect magnetic fields gives some hints about how electric currents are distributed in the trap."

© Getty

H5N8 jumped from bird to human, but there's no evidence of human-to-human transmission yet

HEALTH

Russia finds case of humans catching avian bird flu

Words by **Nicoletta Lanese**

Russian authorities have reported the first known cases of an avian influenza virus, H5N8, passing from poultry to humans. Seven workers at a poultry plant became infected with the virus in December 2020. Scientists at the state-run Vector Institute isolated the virus strains from infected workers, said Anna Popova, head of Russia's Federal Service for Surveillance on Consumer Rights Protection and Human Wellbeing.

Russia reported the seven cases to the World Health Organization (WHO), noting that there was no evidence of human-to-human transmission – the influenza virus jumped from infected birds into people, but it did not continue to spread from human to human. "If confirmed, this would be the first time H5N8 has infected people," said a WHO spokesperson.

Several different avian flu strains are known to infect people, including H5N1, H7N9 and H9N2, but none of these strains have ever caused sustained human-to-human transmission.

People infected with H5N8 "were asymptomatic, and no onward human-to-human transmission was reported," the WHO spokesperson confirmed. Since the virus doesn't appear to pass between people, that "gives us all, the entire world, time to prepare for possible mutations and react in an adequate and timely fashion," said Popova.

WISH LIST

The latest **sleep** gadgets

Bose Sleepbuds II

Price: **£229.95 / $249.95**
www.bose.co.uk / www.bose.com

The humble earplug gets a high-tech upgrade in the form of the Sleepbuds II by Bose. Sleepbuds II are designed to fit seamlessly with the shape of your ear, which helps to shut out sounds alongside built-in noise-cancelling technology, preventing snoring or traffic for keeping you awake. Using the companion app, you can choose from a packed library of white noise tracks and soothing sounds to help you drift off, undisturbed. These earbuds are powered for ten hours on a single charge, and the unique ear tips will hold them in place while you toss and turn in the night.

© Bose

Hatch Restore

Price: **$129.95 (approx. £92)**
www.hatch.co

Hatch Restore is a combination of sound machine, alarm clock, sunrise alarm and meditation app. This smart sleep assistant allows you to schedule your nighttime routine through its companion app. For example, you can program your evening to begin with soothing sounds and soft glowing light, then choose to be woken up with a natural sunlight alarm. This gadget allows you to create a nighttime playlist of all the Hatch Restore features for a good sleep routine.

© Hatch

Pod

Price: **From $2,595 (approx. £1,840)**
www.eightsleep.com

If you're someone who's continually throwing the duvet on and off during the night trying to get cosy or cool, this mattress could be a game changer. The Pod by Eight Sleep is a smartphone-controlled mattress that allows you to change its temperature while you sleep. Pod works using water that flows around the mattress to deliver the desired temperature. This smart mattress also has two zones of temperature control, meaning you can set different temperatures on either side of the bed. Temperatures range from around 13 to 43 degrees Celsius and can be scheduled to match your sleep time.

© Eight Sleep

Moona

Price: **$399 (approx £283)**
en.getmoona.com

Many of us love the refreshingly cool feeling of a flipped pillow. However, Moona is a device that means you always have the feel of a freshly flipped pillow while you sleep. Using a water-cooling system, Moona can circulate temperature-controlled water to your head and neck. Simply place the Moona pad into your pillowcase and set the desired temperature, as low as 18 degrees Celsius, on the Moona app. The device will alter the temperature as you sleep, warming up as you head towards the time to wake up.

© Moona

Sleep Tracking Mat

Price: **$99.95 / £99.96**
www.withings.com

Understand your sleeping pattern with this sleep tracking mat by Withings. Heart rate, breathing and movement are just some of the things this device can monitor thanks to its array of sensors. The tracking mat is placed under your mattress – rather than most sleep trackers, which are worn – and all the collected data is sent to your smartphone. This can help you to monitor the length of your sleep, see your 'sleep score' to evaluate how restful your sleep was, your level of sleep apnea and much more.

© Withings

Dodow

Price: **£49.90 / $59.99**
www.mydodow.com

If you find it hard to fall asleep, this compact device might be able to help. The bedside table gadget projects a blue light onto your bedroom ceiling which expands and retracts. The aim is to match your breathing to the changing light in the hope of bringing your breathing down to six breaths per minute. This speed reportedly brings you into a relaxed state to more easily drift into sleep. The company claims that on average its users have reduced the time it takes them to fall asleep by 61 per cent.

© Dodow

APPS & TOOLS

Sleepa

Developer: **Sound Sleep**
Price: **Free / Google Play**

This app is filled with relaxing sounds and ambiences to help you fall fast asleep and comes with an automatic timer to shut them off once you've drifted off.

Sleep Monitor: Auto Sleep Track

Developer: **SM Health Team**
Price: **Free / Google Play / App Store**

From snore recording and a movement tracker to studying your sleep cycle, this app is full of features that measure how you well you sleep.

Lucid – Dream Journal

Developer: **Learn Lucid Dreaming**
Price: **Free / Google Play**

If you have trouble remembering your dreams, this dream journal helps you to organise them and offers advice on how you can induce a lucid dream.

Moshi

Developer: **Mind Candy Ltd**
Price: **£29.99 / $40 per year / Google Play / App Store**

The digital answer to a bedtime story, this app has original audio, meditations and sounds narrated by legends such as Patrick Stewart.

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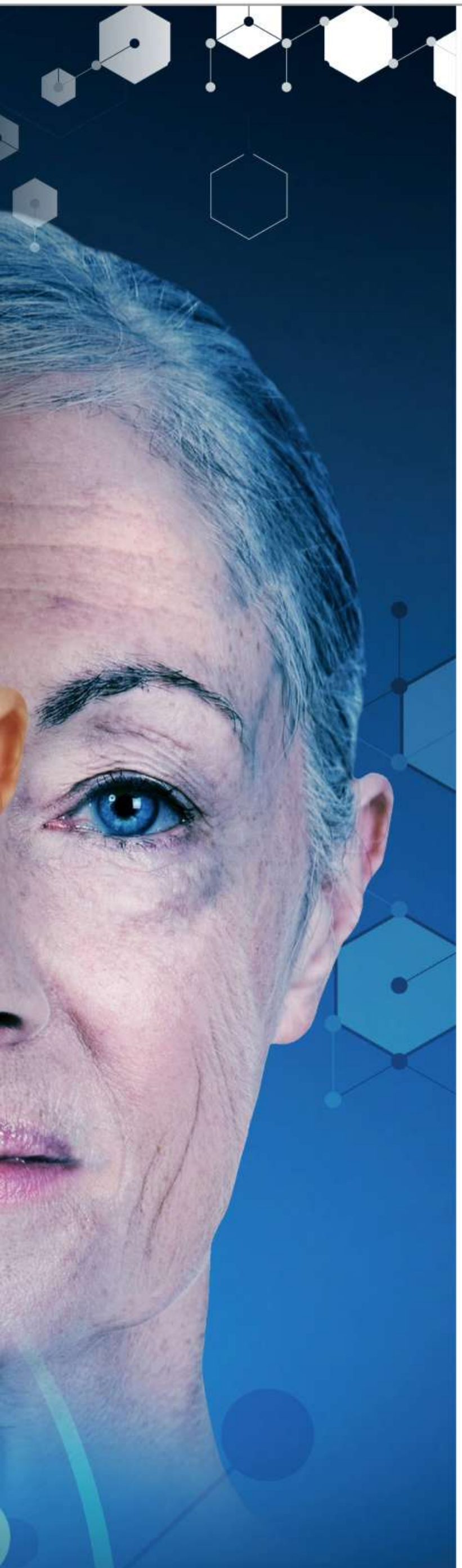


CAN WE LIVE FOREVER?

What is ageing and why do we get older? **How It Works** looks at the science of senescence and the technologies tackling the inevitable

Words by **Scott Dutfield**

Ageing is a fact of life we can't escape no matter how hard we try, though as a species we're getting better at prolonging the process. For the first time in human history, the global average life expectancy is above 70 years old. In comparison, back in 1950 the global average was only 45 years old. We can predominantly thank the advancement of medicine for letting us live longer, but at what point do we stop growing and start ageing?

It's generally understood that once we surpass sexual maturity in our late 20s we make the transition from developing into ageing, also referred to as senescence, which means 'the process of growing old'. After sexual maturity, our bodies become less efficient at dealing with physical stress and maintaining biological systems. That seems to be because of the way our species has evolved.

It might make more sense that, like any machine, if you keep your body well-fuelled and maintained, you could live indefinitely. Generally speaking, many evolutionary biologists have concluded that we age simply because the driving force of evolution, known as natural selection, hasn't selected for fitness and function at an older age.

Of course, humans aren't alone in this. The majority of other species have evolved a similar reproductive life cycle – but not all of them. Many cold-blooded species such as lizards retain their fitness and reproductive abilities and are considered to have negligible senescence. These animals age very slowly and typically die from non-age related events such as predation, disease or natural disasters.

CELLULAR AGEING

Although we recognise ageing in humans as wrinkled skin, joint pain and grey hair, senescence occurs on a much smaller scale. More than 37 trillion cells make up the human body, and each one will have its own life cycle that contributes to your body's overall ageing.

Each of your cells has a Hayflick limit, named after the scientist Leonard Hayflick, who discovered it. This limit is how many times a cell can divide before it can't divide anymore and dies. A normal human cell has a Hayflick limit of between 40 and 60 divisions. This is because

AR ZONE!

Cell shutdown

How apoptosis systematically destroys cells

Shrinking
Once an internal signal triggers the beginning of apoptosis and self-destruction, the cell membrane begins to shrink.

Blebbing
The membrane puckers and forms bulbous structures called blebs.

Complete collapse
Organelles, such as the cell's nucleus and mitochondria, are broken down within by internal enzymes.

Breaking apart
The cell membrane breaks up after blebbing, forming small pockets of apoptotic bodies.

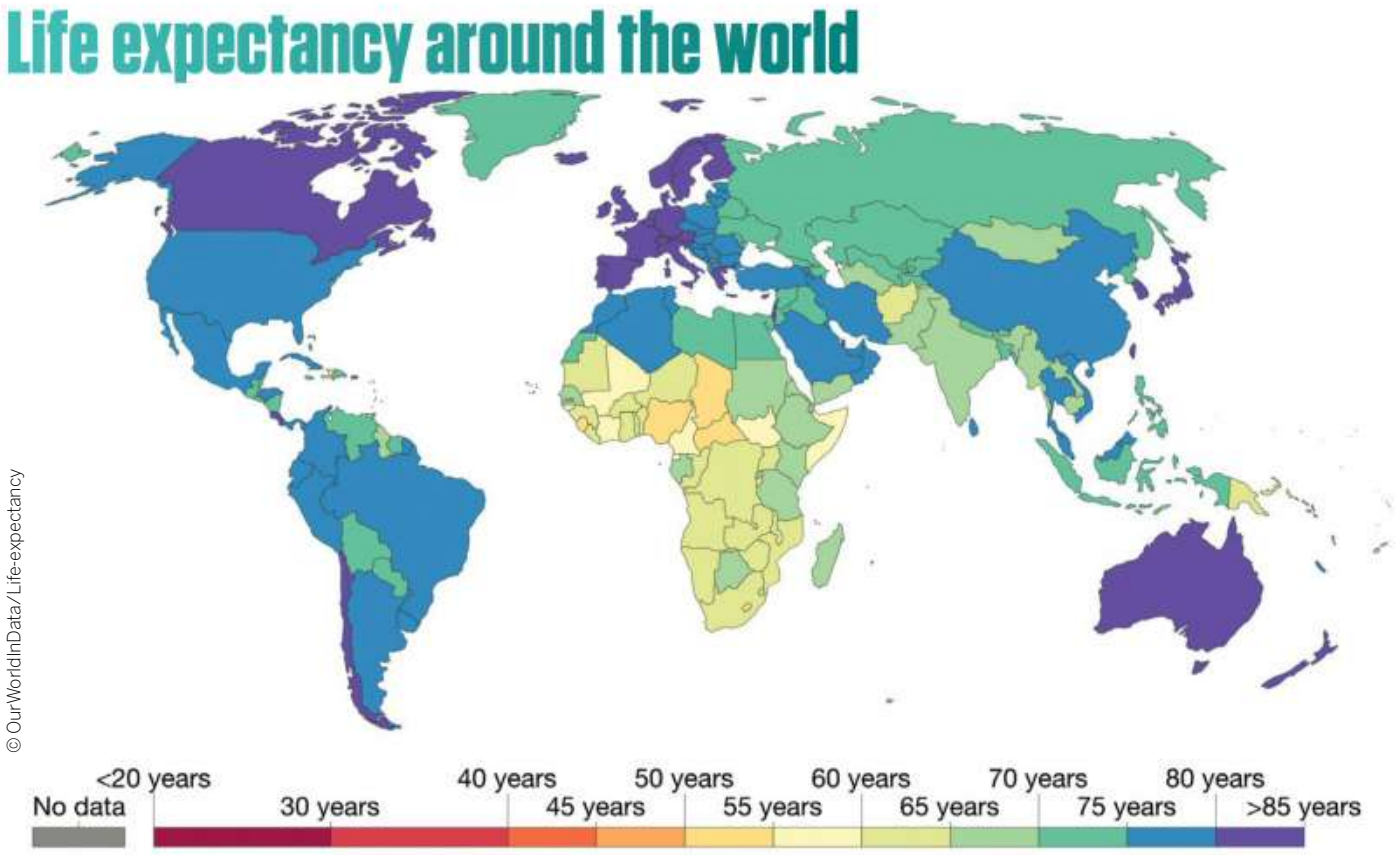
Digestion
Large immune cells called macrophages engulf the apoptotic bodies and destroy them.

An animation of three cells in programmed death. Scan the AR code to watch them being broken down

AR ZONE! SCAN HERE

© Alamy

© Getty



© OurWorldInData/Life-expectancy

with each division cells lose some genetic information. Long chains of DNA called chromosomes in the cells' nuclei lose non-coding sequences of DNA called telomeres from their tips. With each replication these telomeres become shorter and shorter, until the cell can no longer successfully divide.

Reaching their limitations, cells will undergo a form of self-destruction called apoptosis, from the Greek word for 'falling off', referring to leaves on a tree. This orderly process involves enzymes, called DNases, breaking down a cell's genetic information. Immune system cells called macrophages eat up the cell's remains and remove it. This is different from necrosis, however, whereby a cell will die away after it is physically damaged.

This cellular life cycle is what keeps our bodies in check; without a Hayflick limit, cells would continue to divide, growing to form masses. For example, cancer cells have no Hayflick limit, which is why they grow rapidly and form tumours that can spread around the body easily.

However, it is believed that when a cell's DNA is damaged, the process of apoptosis is halted, and the cells become 'senescent'. Stuck in a phase between being alive and dead, these are often referred to as 'zombie cells'. They can no longer perform their allocated function, and they also stop reproducing. As a result, the cells build up and become a major contributor to the process of ageing.

As these zombie cells linger over time, they cause inflammation and other age-related diseases such as cancer and cardiovascular disease. They play a particular role in the degradation of neighbouring tissue and cells, which leads to the development of degenerative disorders related to age such as dementia.

© Alamy

This is the oldest person alive, Kane Tanaka, who celebrated her 118th birthday this year

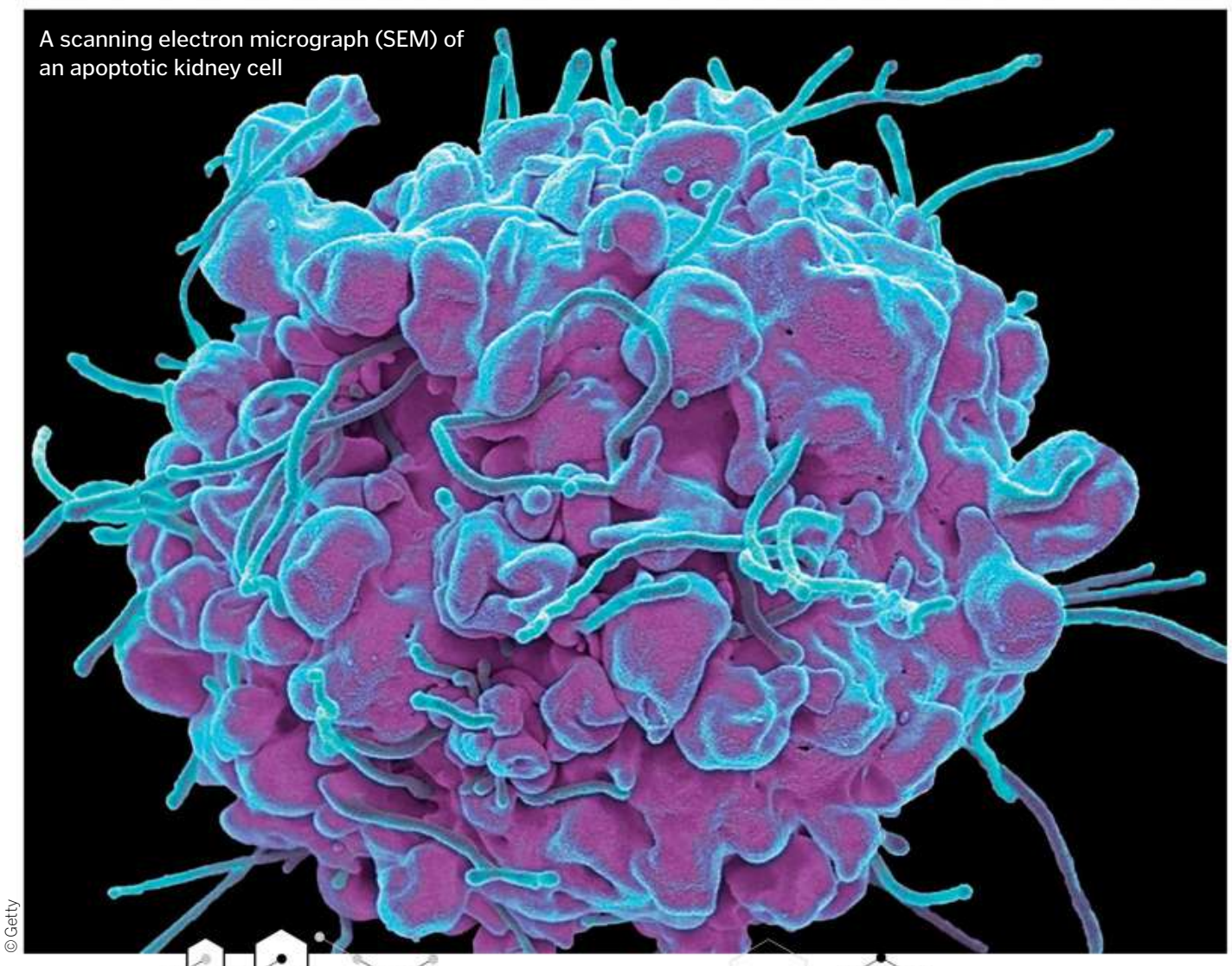
Too old to age

Is it possible for a human body to reach a certain age and just stop ageing? A study conducted in 2018 found that yes, it can happen, but you have to reach 105 years old first. Research conducted at the Sapienza University of Rome in 2018 found that, when looking at 3,836 Italians who were over the age of 105 between 2009 and 2015, the risk of death plateaued.

As we age our risk of death naturally increases – for example, in your 50s the risk of dying is three-times higher than in your 30s. However, the study suggests that the probability of living between 106 and 107 years is the same as 111 and 112 years. It remains unclear as to why this might be, with the need for more study into potential contributing factors, such as genetics.

© Getty

If you reach your 100th birthday, you have a 60 per cent chance of celebrating your next one



A scanning electron micrograph (SEM) of an apoptotic kidney cell

© Getty

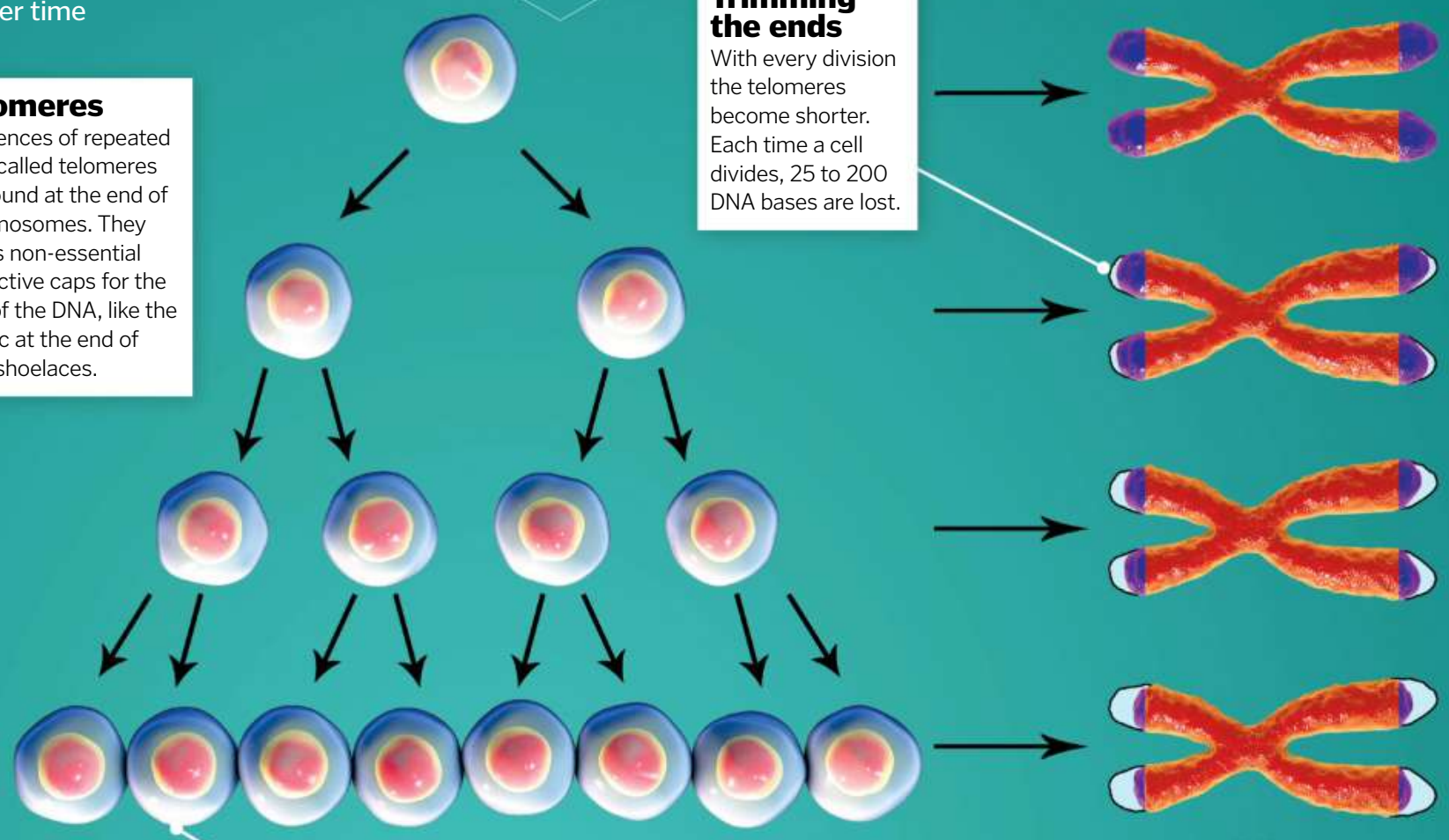
Cutting chromosomes

Here's how telomeres shorten over time

© Getty

Telomeres
Sequences of repeated DNA called telomeres are found at the end of chromosomes. They act as non-essential protective caps for the rest of the DNA, like the plastic at the end of your shoelaces.

Trimming the ends
With every division the telomeres become shorter. Each time a cell divides, 25 to 200 DNA bases are lost.



Chromosome
Each cell in our bodies contains 23 pairs of long DNA chains called chromosomes.

Cell division
Human cells can divide 40 to 60 times before reaching their Hayflick limit. However, stem cells have a few more, around 72 times.

Forming wrinkles

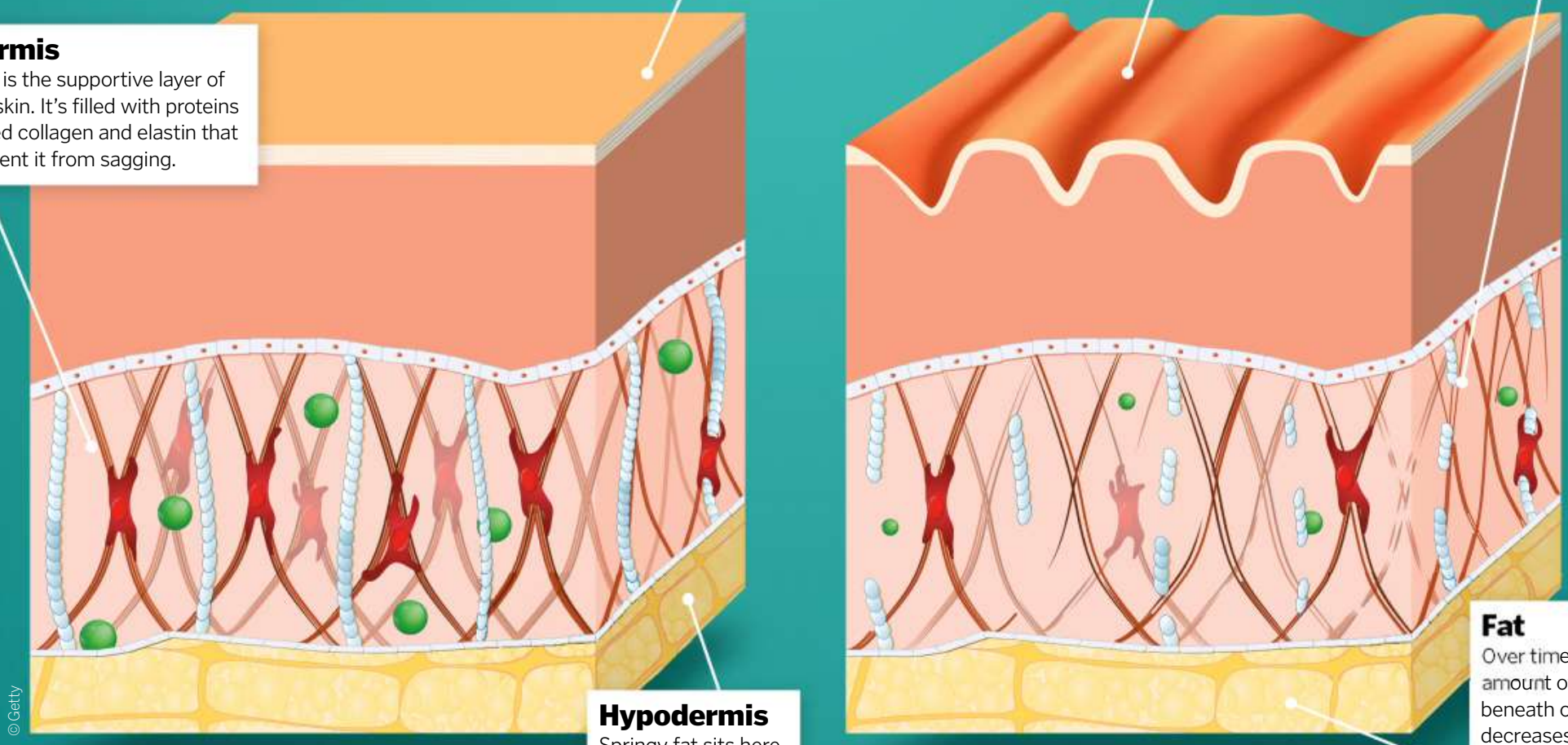
How skin folds to create laugh lines

Epidermis
Younger skin is packed with lots of moisture, keeping it smooth and plump.

Moisture
Wrinkles begin to form when a lack of moisture causes skin to fold into the dermis layer.

Collagen
Levels of collagen and elastin are diminished over time, which act like support beams for the epidermis.

Dermis
This is the supportive layer of the skin. It's filled with proteins called collagen and elastin that prevent it from sagging.



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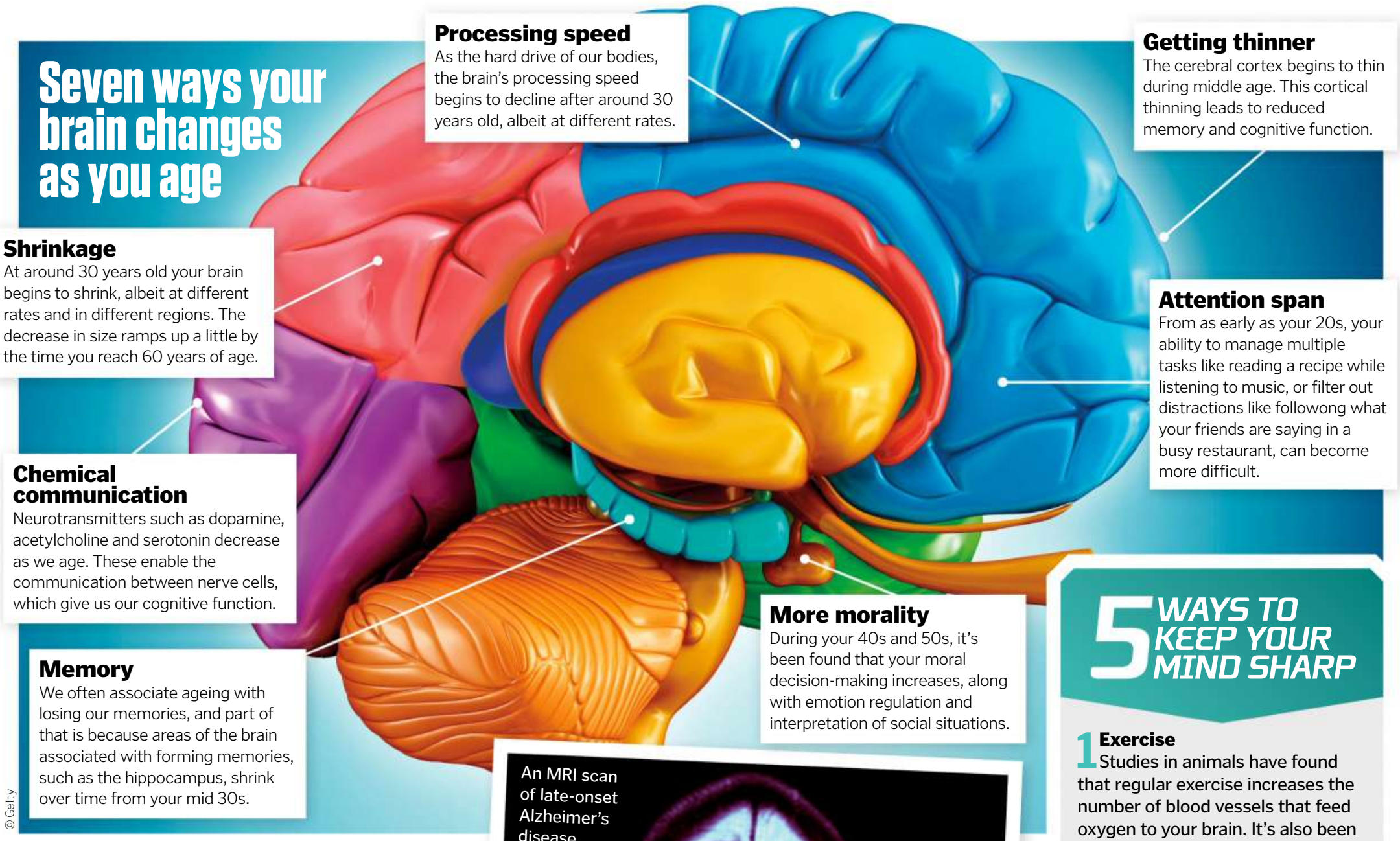
YOUNGER SKIN

Hypodermis
Springy fat sits here, forming a structural foundation for the layers above.

OLDER SKIN

Fat
Over time the amount of fat beneath our skin decreases further, allowing the above layers to sag into one another.

Seven ways your brain changes as you age



Processing speed
As the hard drive of our bodies, the brain's processing speed begins to decline after around 30 years old, albeit at different rates.

Getting thinner
The cerebral cortex begins to thin during middle age. This cortical thinning leads to reduced memory and cognitive function.

Shrinkage
At around 30 years old your brain begins to shrink, albeit at different rates and in different regions. The decrease in size ramps up a little by the time you reach 60 years of age.

Attention span
From as early as your 20s, your ability to manage multiple tasks like reading a recipe while listening to music, or filter out distractions like followong what your friends are saying in a busy restaurant, can become more difficult.

Chemical communication
Neurotransmitters such as dopamine, acetylcholine and serotonin decrease as we age. These enable the communication between nerve cells, which give us our cognitive function.

More morality
During your 40s and 50s, it's been found that your moral decision-making increases, along with emotion regulation and interpretation of social situations.

Memory
We often associate ageing with losing our memories, and part of that is because areas of the brain associated with forming memories, such as the hippocampus, shrink over time from your mid 30s.

© Getty

An MRI scan of late-onset Alzheimer's disease

© Getty

THE APPEARANCE OF AGEING

Greying hair is a universal symbol for ageing. It's commonly misunderstood that your hair 'turns' grey, when in fact it's just your hair follicles running out of pigment over time. This biological hair dye is called melanin, and it's also the pigment that gives your skin its colour. As we age, the production of melanin at the follicles declines, and grey hair begins to emerge, typically from your 30s. Around 50 per cent of the population will be at least partially grey by the time they are 50. But melanin decline isn't exclusive to hair follicles as we age. Our number of melanin-containing skin cells, called melanocytes, decreases by 8 to 20 per cent per decade after the age of 30.

Along with the loss of melanin, our skin also loses components that keep it firm and smooth, such as collagen and elastin. After the age of 20, a person makes around one per cent less collagen in their skin every year. This leads to the formation of wrinkles, and generally less plump skin. What do appear to continue to grow, however, are our ears and noses. Researchers at the University of Milan calculated that the total surface area of the nose of people aged 65 to 80 years old is typically 15 per cent larger than a nose on the face of an 18 to 30 year old. This is because as we age, the cartilage that has built those features goes through a process that makes it thicker but less elastic.

The process of ageing doesn't affect us all equally. Many of us go grey or lose our hair sooner than others, and wrinkles will appear at different stages of our lives. Our bodies are unique and are affected by our genetic blueprints and the impact our environment has on us, meaning that everyone ages at different rates. A study from Duke University explored this on a cellular level. Researchers monitored different markers for risks of age-related disease, metabolism and the length of telomeres of 1,000 participants. The researchers checked in on them at 26, 32 and 38 years old, and found that in general, participants' biological age correlated with how many birthdays they had celebrated. However, there were some extreme exceptions. One participant had a biological age of 28 – essentially not ageing since the trial began – while another had biologically aged to around 61. That suggests that they aged three years for every birthday on average.

5 WAYS TO KEEP YOUR MIND SHARP

1 Exercise
Studies in animals have found that regular exercise increases the number of blood vessels that feed oxygen to your brain. It's also been found that new nerve cells and the connections between them are increased, which improves your cognitive abilities.

2 Sleep
Getting seven to eight hours of sleep a night has been found to consolidate memories more efficiently. Some studies have found that bad sleep increases proteins in the brain that contribute to impaired brain function.

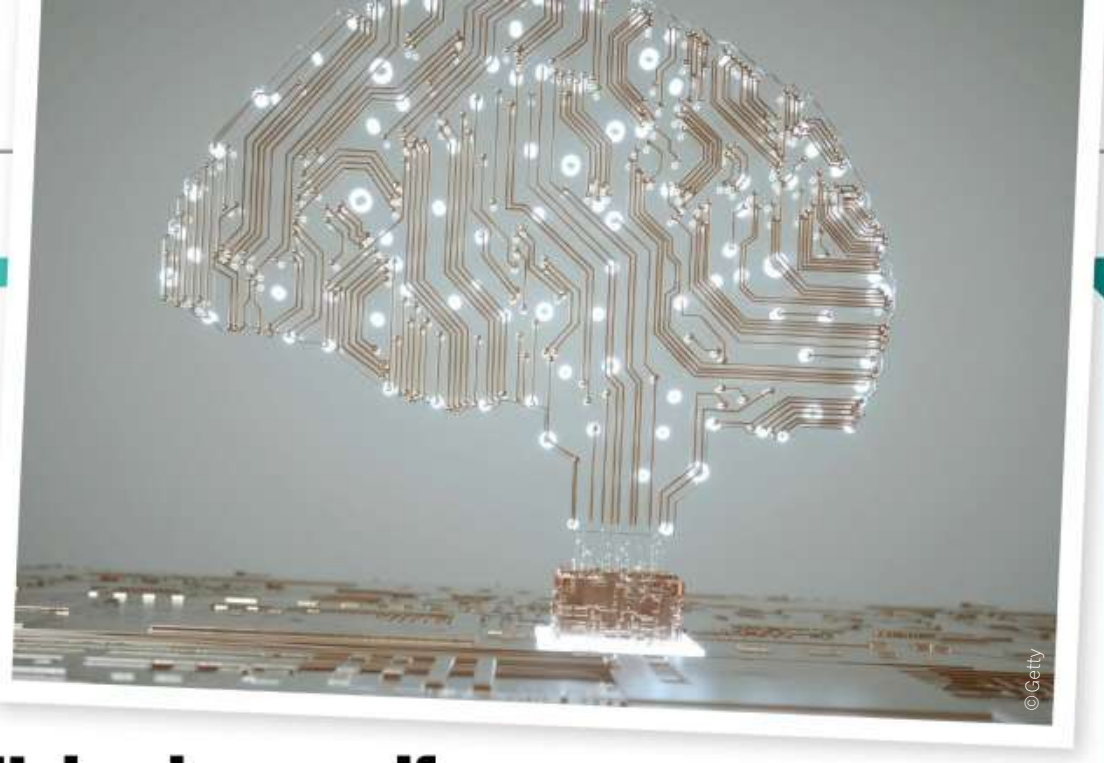
3 Eat well
Having a healthy diet will improve many aspects of your life, but studies have shown that those eating a Mediterranean-style diet filled with vegetables, nuts, fish and fruit are less likely to develop conditions such as Alzheimer's.

4 Stay social
Social interactions have never been more important to our mental health, but regarding ageing, safe social interactions help prevent the effects of depression and stress, which contribute to memory loss.

5 Train your brain
Completing puzzles such as jigsaws, sudoku or crossword puzzles stimulates new connections between brain cells and develops your brain's ability to problem solve and adapt to new situations.

WHO WANTS TO LIVE FOREVER?

The science that seeks to slow down the process of ageing



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Uploading our minds might be possible with future technology

Upload yourself

There may come a point when attempts to prevent ageing turn from the biological to the digital. If you truly want to live forever, then uploading your brain may be a real option in the future. When, however, remains unclear. The science is called Whole Brain Emulation (WBE), and in theory it would involve uploading your consciousness into a computer, including all of your thoughts and feelings. However, the first and biggest hurdle scientists face is mapping the human brain. There are roughly 86 billion neurons in your head and each neuron can connect to 10,000 other neurons. Thus far scientists have only been able to map the 302-neuron brain of a nematode, so we're a long way off navigating the human mind. Nevertheless, many tech companies and research institutes are working to map the whole brain in the hopes of one day recreating it online.

Anti-ageing pills

Could stopping the process of ageing be as simple as popping a pill? Researchers at the Mayo Clinic in Minnesota have been developing so-called senolytic drugs. These pills work by inducing apoptosis in senescent cells, preventing them from gathering. This prevents them from damaging neighbouring cells and causing age-related illnesses. So far this type of time-halting medicine has only been successfully trialled with animal subjects, though human trials are underway.

Senolytic drugs are not yet available, but could one day revolutionise the way we age

© Getty

Inducing self-destruction

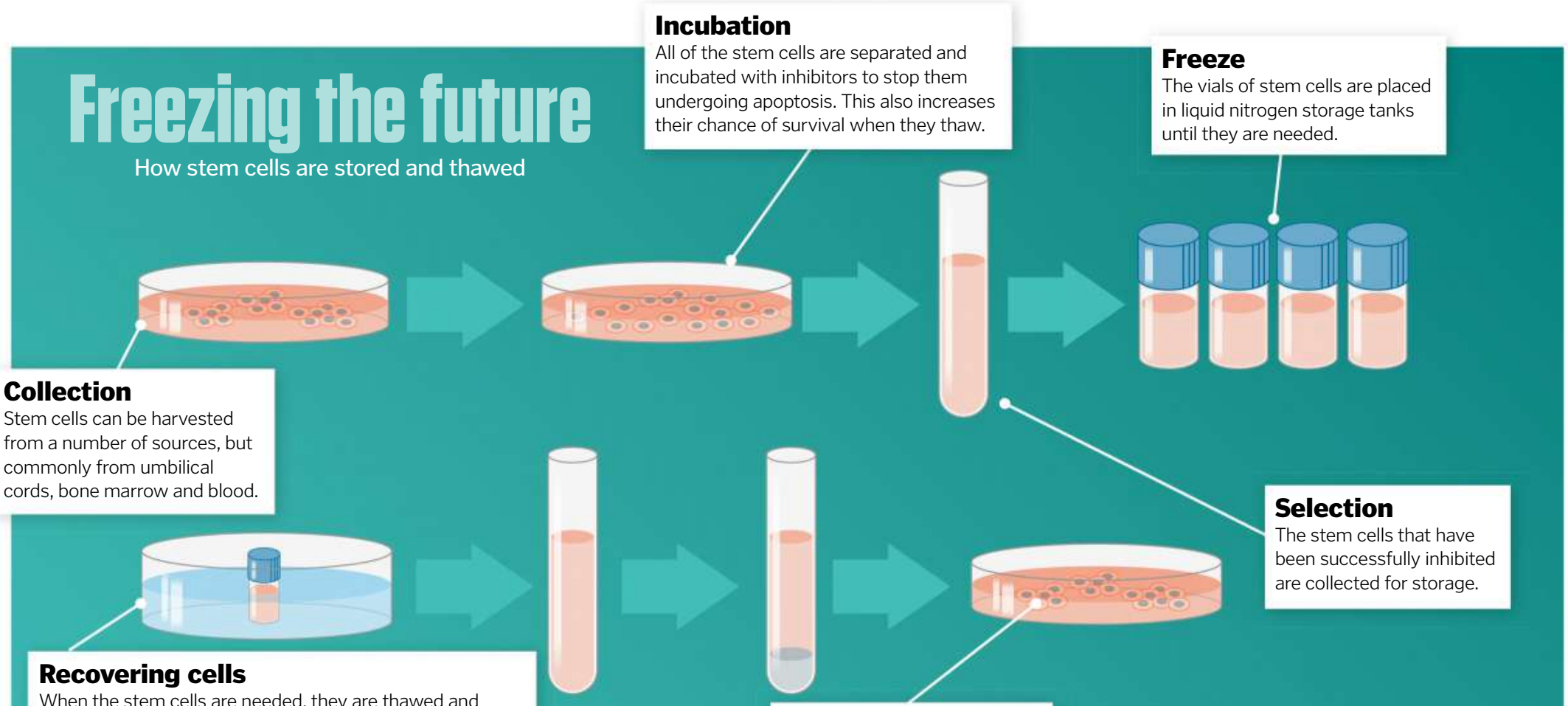
How senolytic drugs could keep us young

Normal tissue
Senolytic drugs are designed to only induce cell death in senescent cells, preventing them from causing tissue damage.

Senescent cells
These release inflammation-causing molecules that contribute to the development of age-related diseases such as cancer and osteoporosis.

Cell death
Once kicked back into gear, apoptosis breaks apart the cells, which will later be hoovered out by the body's immune system.

Active ingredient
Senolytics enter the membrane of the senescent cells and interfere with proteins to kick-start the process of apoptosis.


Freezing the future
How stem cells are stored and thawed
Incubation
All of the stem cells are separated and incubated with inhibitors to stop them undergoing apoptosis. This also increases their chance of survival when they thaw.
Freeze
The vials of stem cells are placed in liquid nitrogen storage tanks until they are needed.
Collection
Stem cells can be harvested from a number of sources, but commonly from umbilical cords, bone marrow and blood.
Selection
The stem cells that have been successfully inhibited are collected for storage.
Recovering cells
When the stem cells are needed, they are thawed and diluted. These can now be reinfused into the patient's body.
Healthy cells
Once prepared and cultured, the stem cells can be injected into the patient, where they travel to the bone marrow and start producing healthy cells.

Stem cell security

One way people are clinging to the hope of eternal youth is by cryogenically freezing their stem cells. Stem cells are special cells that can transform into any other type of cell in your body. By storing these cells, the hope is that one day they can be used for treatments to battle any future illnesses.

Currently the only stem cells used to treat conditions are those that change into blood cells for transplants in blood cancer patients. These cells can be harvested from sources such as the umbilical cord at birth, adult bone marrow or fat tissue. The cells are then frozen and stored for future use.

Young blood myth

Could transfusing the blood of young people keep you youthful? Probably not

© Getty

People have gone to extreme lengths to preserve their youth, both cosmetically and biologically. However, in February 2019 the US Food and Drug Administration cautioned the public about receiving blood transfusions from young people in attempts to turn back the biological clock, saying that this had "no proven clinical benefit". Transfusions were being offered by companies such as California start-up Ambrosia, with a price tag of $8,000 (around £5,780) per litre of blood plasma – the liquid component of blood – from people aged between 16 and 25 years old. Claims that the protein-filled plasma could help with ageing-related ailments and diseases, such as inflammation and Alzheimer's, have not been substantiated by a great deal of scientific research, with limited studies investigating if the vampiric therapy provides any health benefits.

© Getty

Pure oxygen and a pressurised chamber could be the key to unlocking a long life

Breathing young

A recent study conducted at Tel Aviv University has revealed that hyperbaric oxygen treatments could halt the ageing process. Over a research period of 90 days, 35 participants over the age of 64 were given hyperbaric treatments, which involved inhaling pure oxygen in pressurised environments for 90 minutes a day, five times a week.

Blood tests showed that the bodies of the participants changed on a cellular level to what they would have been like 25 years earlier. Researchers found that telomeres lengthened by 38 per cent, and a 37 per cent decrease in the presence of senescent cells. More research is needed to fully understand how hyperbaric treatments may intervene in the process of ageing, but it's a promising start.

AR ZONE!

IMMORTALITY

Is the future of everlasting life cryonics?

© Getty

One way in which you could give yourself the opportunity to live even after death is with cryonic suspension. It may have been able to bring back Austin Powers after 30 years of suspension, but beyond the world of science fiction, the practicalities of cryonics remain a mystery. Right now we have the technology to cryogenically preserve a human body, but remain clueless on how to revive them when the time is right. It's the belief that humankind will one day find a way to successfully thaw patients and treat whatever illnesses led to their death. The world leader in cryonics, Alcor, currently has 181 patients and has been storing humans for 49 years, including the company's founder, Fred Chamberlain.

The process of preserving a human body through cryonics involves replacing the water content of a body with a chemical cryoprotectant, which works like antifreeze. This is to prevent ice crystals forming during freezing and irreversibly damaging the body. Once filled with cryoprotectants, the body will eventually be placed into a tank of liquid nitrogen at around -196 degrees Celsius, where it will be stored.

Currently the biggest challenge of cryonics is to find out how it can allow people to be brought back to life. Science has successfully frozen simple cells such as eggs and sperm in suspension and thawed them with their functions intact. However, the same can't be said for the entire body. It remains unclear as to how scientists will bring back an entire, functioning human body. So far the only success scientists have had has been in bringing functionality back to the cryogenically frozen brain of a small rabbit.

We've got the science to safely cryopreserve the dead, but we're still unsure how to revive them

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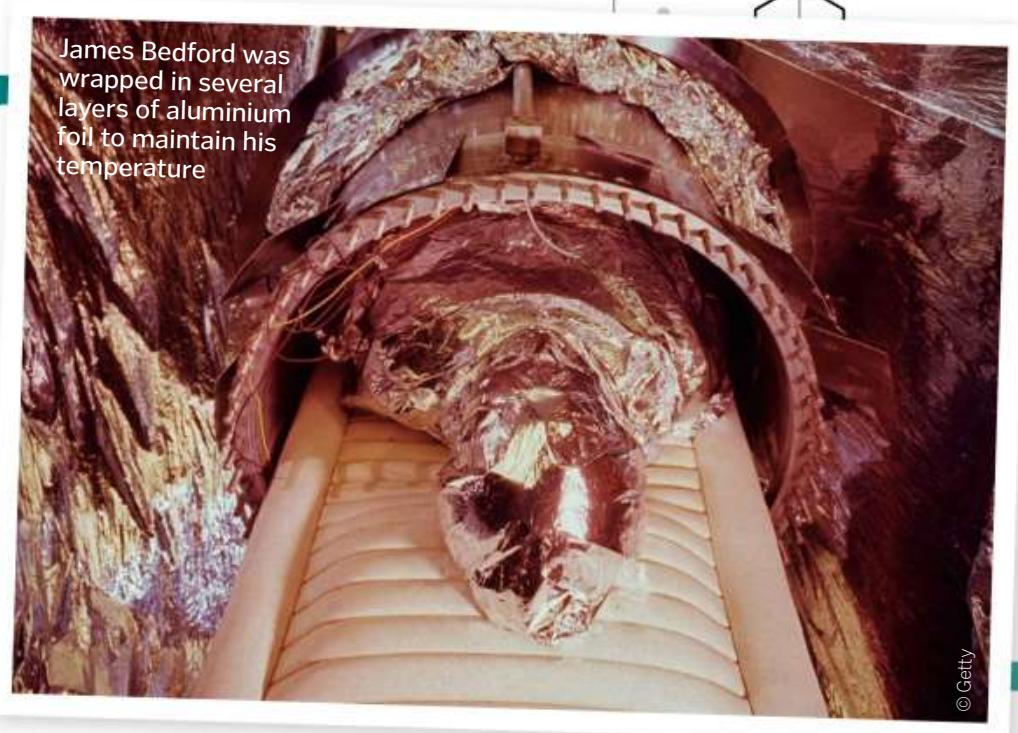

James Bedford was wrapped in several layers of aluminium foil to maintain his temperature
© Getty

First cryogenic human

The first person to ever be cryogenically frozen was Dr James Bedford, a 73-year-old psychologist who died of cancer. In 1967, Bedford entered a cryogenic storage dewar, a special vacuum flask to store super-cold cryogens such as liquid nitrogen. Upon his death, Bedford's blood circulation was artificially maintained while he was being cooled. His body was injected with dimethyl sulphoxide, which can preserve tissue, before being moved to a liquid-nitrogen environment. It's since been found that this method of preservation will have most certainly damaged the cells in Bedford's brain beyond any possible repair. Nevertheless, his body remains on ice at the Alcor Life Extension Foundation to this day.

Inside the cryo coffin

From death to deep freeze, here's how the human body is preserved

DEATH

Artificial breathing
Within minutes of death, the body has to be put onto a mechanical heart-lung ventilator to keep the brain supplied with oxygen.

COOLING

Preparation
The body is packed with ice and injected with a blood-thinning drug called heparin to prevent the blood from clotting before being transported to a cryogenic facility.

HEPARIN

Human antifreeze
A cocktail of chemicals is injected into the body to act as 'human antifreeze', replacing any water content in the body to prevent the formation of ice crystals.

ANTI-FREEZE

Chill out
The body is then placed on dry ice and cooled until it reaches around -130 degrees Celsius.

FREEZING

Cryonic chamber
Up to six bodies are held in a tank of liquid nitrogen, which reaches and is maintained at around -196 degrees Celsius.

CONTAINER

AR ZONE! SCAN HERE

© Illustration by: Adrian Mann

HOW WE USE OIL

Known as 'black gold', oil's versatility has fuelled progress – and problems

Words by **Andy Extance**

© Getty

Oil shapes the modern world, giving humans enormous power, but creating massive environmental problems too. It's strange to think, but much of the furniture we sit on and fill our homes with and everything else plastic that surrounds us owes its existence to oil. Likewise, burning oil and using its energy is still what lets most of us travel nearly anywhere we want.

How can oil – thick black, brown or yellow goop that someone pumped up from deep underground – be so useful? It's because it's rich in the element carbon. Carbon atoms readily bond to each other, and to atoms of other elements. Plugged together like tiny building blocks, these atoms make many different-sized chains and other shapes. Some help form cells in animals – including us humans – and plants.

"Carbon atoms bond to each other, and to atoms of other elements"

Over millions of years, formerly living material sinks to the bottom of lakes and seas. It gets buried there and slowly changes into a valuable, sticky liquid. We pay an enormous industry billions a year to suck that oil out. Then companies separate it into different parts, each of which does a useful job. However, every barrel of oil we pump up brings both challenges and benefits. When we separate out the parts of oil and then make things from them, we usually want them to last a long time. So when we throw them away, they stay in our environment and pollute it. Perhaps even worse, when we burn oil for energy, its carbon atoms combine with oxygen in the air to become carbon dioxide. This acts like an invisible blanket in the atmosphere, trapping heat, leading to dangerous global warming. Oil's usefulness means we still use it, and will keep doing so. Yet we must be more careful to stop oil's problems outweighing its benefits.

Because plastic is durable, it can stay in the ocean for a very long time

© Alamy

Cleaning up our oceans

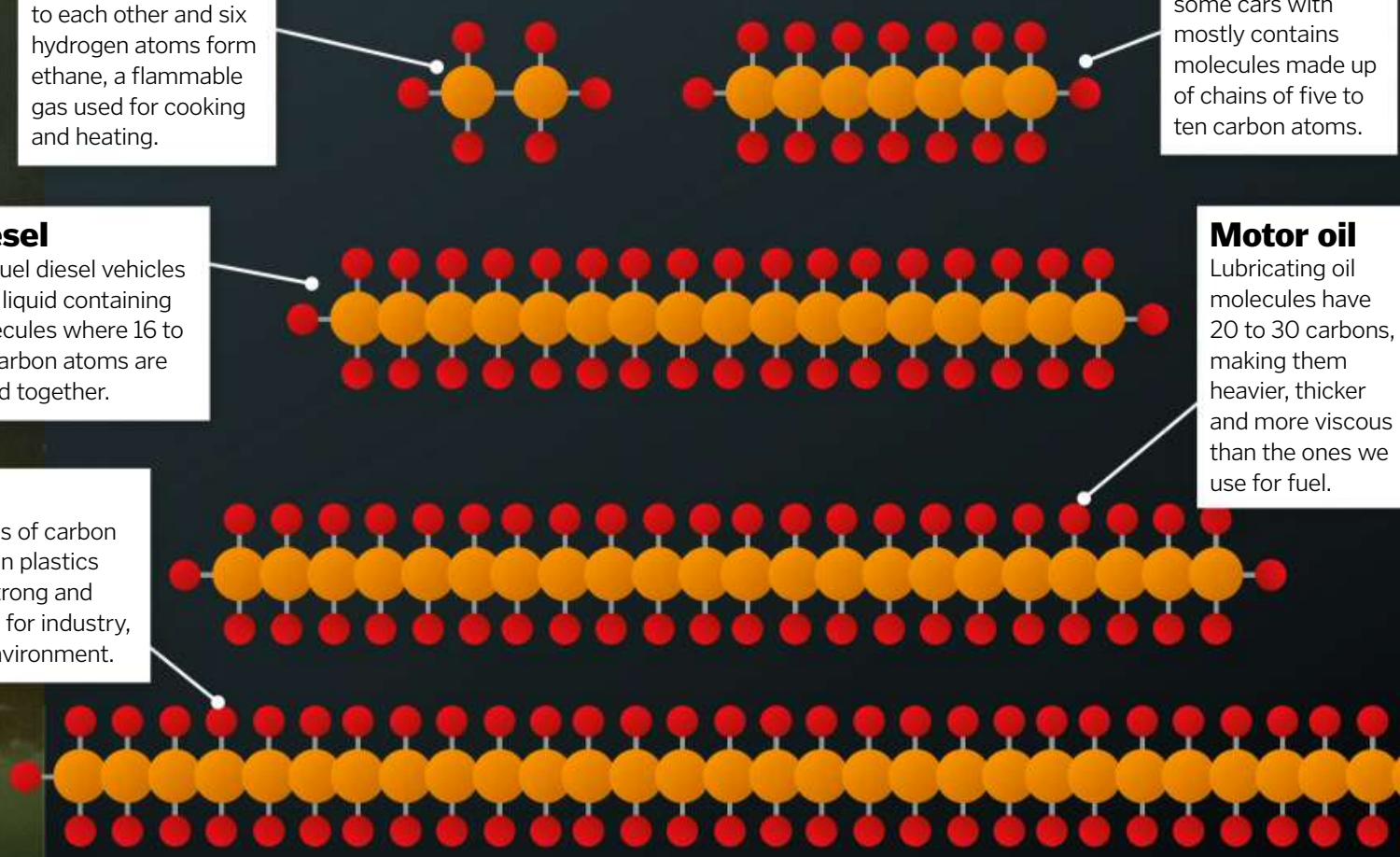
"Industrial pollution and the discarding of plastic waste must be tackled for the sake of all life in the ocean," said naturalist David Attenborough in the 2017 documentary series *Blue Planet II*.

Companies have tried to recycle plastics to fight the plastic problem for a long time. However, very few of the many types of plastic are easily recyclable. In European Union countries in 2017, nearly a third of all plastic was recycled on average. In the US in the same year, less than a tenth of plastic generated was recycled.

Research might be able to help. Some scientists are developing new methods to make recycling easier and more profitable. Recently others have helped speed up how fast bacteria eat up plastic. That would help return the plastics to the oil-derived materials they were made from. But not wasting plastic products in the first place remains an important course of action.

CARBON'S FLEXIBLE BACKBONES

Carbon can bond to four surrounding atoms, so can form chains and many other shapes



Ethane
Two carbons bonded to each other and six hydrogen atoms form ethane, a flammable gas used for cooking and heating.

Petrol
The liquid we fuel some cars with mostly contains molecules made up of chains of five to ten carbon atoms.

Diesel
We fuel diesel vehicles with liquid containing molecules where 16 to 20 carbon atoms are linked together.

Motor oil
Lubricating oil molecules have 20 to 30 carbons, making them heavier, thicker and more viscous than the ones we use for fuel.

Plastic
The thousands of carbon atoms linked in plastics make them strong and durable: good for industry, bad for the environment.

A REFINED PROCESS

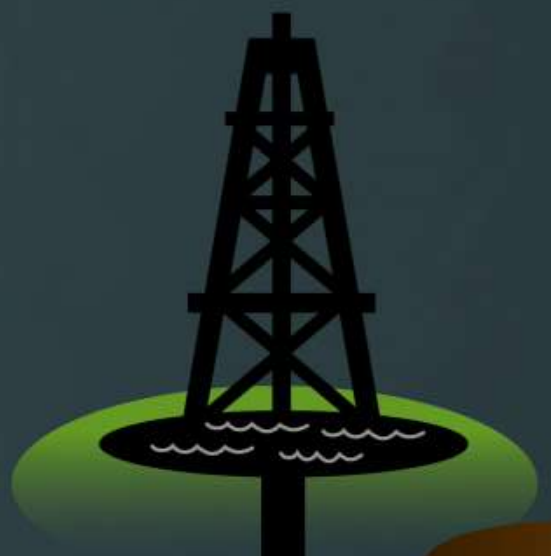
Cooled columns in refineries separate oil into different useful parts according to their boiling temperature

© Alamy

This valley used to be filled with ice, but climate change has melted it

© Alamy

Because plastic is easy to shape, it's used to create many items, like furniture



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Crayons

Paraffin wax has around 20 to 40 carbon atoms per molecule. It is combined with different colour pigments to make crayons.

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Ethylene

Also known as ethene, small ethylene molecules can join up with each other to make the very common plastic polythene.

© Getty

Aspirin

Many drugs originate from oil-based chemicals. For example, aspirin is made from phenol.

Hair dye

Phenol molecules are often highly coloured, meaning that they're used in hair dyes.

Sunscreen

Phenols can offer protection from the Sun, so are used in sunscreen.

Petrol

After separation from crude oil, the petrol that powers many cars is usually a clear, light-yellow colour.

Wax paper

Applying petrochemical naphtha wax to paper makes it waterproof because water doesn't mix well with oily substances.

© Getty

Natural gas

The gas that many people use to cook and heat their homes includes the small hydrocarbon molecules methane and ethane.

Refinery gases

These gases are by-products of oil refinement, but are useful in their own ways.

© Getty

Polypropylene

Some very small petrochemical gas molecules can connect with each other to make plastic. Propylene makes polypropylene, used in Tupperware.

Candles

In the heat of a flame, naphtha wax melts and then boils to form a gas that burns.

Virgin light naphtha

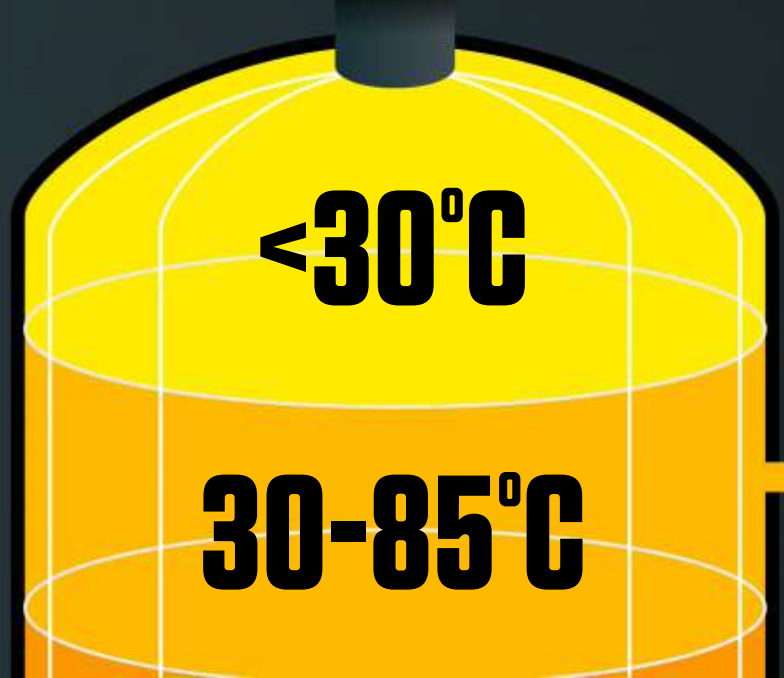
This contains most of the hydrocarbons with six or fewer carbon atoms.

Phenol

A volatile, crystalline solid, it is mildly acidic and can cause chemical burns, so must be handled with care, though it's used in many household products.

Naphtha

Petrochemical naphtha wax contains molecules with 9 to 11 carbon atoms, sometimes looped into rings, and is often broken into smaller hydrocarbons.



Petroleum blending components

These are the different grades of petroleum, such as 83 octane.

www.howitworksdaily.com

CRUDE OIL

Refining crude oil by heating it allows its different components to be separated and removed for use for many purposes.

85-175°C

Virgin heavy naphtha

Contains most of the hydrocarbons with six or more carbon atoms.

Thermosets

Thermosets are irreversibly hardened by heat.

Epoxy resin
Propylene from naphtha can go into making epoxy resins, which are thermoset.

Synthetic rubber
Once taken from trees, scientists found they could make it from naphtha.

Thermoplastics

These materials become softer when heated, and harder when cooled.

Vinyl
The black records on which music is recorded are made from polyvinyl chloride (PVC) plastic.

© Getty

Nylon
Breaking down naphtha into rings of six carbon atoms produces one of the ingredients that makes nylon.

Teflon
Teflon adds fluorine atoms to ethylene, which can come from either natural gas or naphtha.

175-235°C

Kerosene

Also known as paraffin, this highly flammable derivative of petroleum is used as a fuel in aviation and households.

Camping fuel
The fact that kerosene contains a lot of energy makes it good for hikers who must carry small stoves.

© Getty

235-345°C

Diesel

As cars that use diesel fuels pollute city air and can damage people's health, they are becoming less popular.

Jet fuel
Aircraft are powered by kerosene because it burns well and contains a lot of energy.

© Getty

Diesel fuel
Diesel engines don't require a spark to ignite like petrol ones, using compression of the inlet air mixture instead.

Heating oil
Houses not connected to other heating networks are warmed by oil-powered heating, which is similar to diesel or kerosene.

345-565°C

Mineral oils

Viscous mineral oils are made up of long-chain carbon molecules arising from refining, and are often used as lubricants.

Motor oil
Lubricant liquids in vehicles and other large machines are made from molecules that have long chains of carbon atoms.

© Alamy

Petroleum jelly

Petroleum jelly's soft and slick texture comes from its mixture of hydrocarbons, mainly with more than 25 carbon atoms in them.

© Getty

Moisturiser
Using petroleum jelly to form an oily barrier on your skin can stop it losing moisture.

Lip balm
The fact that oil and water don't mix means petroleum jelly can stop water escaping your lips.

>565°C

Residual fuel oil

This is one of the cheapest oil products because it's made of very long carbon chains, making it very sticky.

Ship fuel
Big ships use very thick residual fuel oil, which needs to be heated up to be pumped into their engines.

Power plant fuels
Using residual fuel oil to generate electricity emits lots of planet-warming carbon dioxide, so this is generally becoming less common.

BITUMEN

The thick, semi-solid bitumen left behind after oil refining can be used to make roads and roofs.

"Oil is useful because it's rich in the element carbon"

DID YOU KNOW? *Petrol used in cars and jet fuel both contain nearly three times as much energy by weight as wood does*

Bone scintigraphy is a form of nuclear medicine that shows the extent of cancer's spread in bones

© Alamy

Treating cancer with nuclear medicine

How radiation can be used to detect and target tumours

Words by **Ailsa Harvey**

Irradiating the human body is usually a bad idea, as radiation can alter or kill cells. But what if that's the goal? For cancer patients, the application of this destructive energy can be used to rid the body of unwanted cells. Cancer is caused by the uncontrolled division of cells, which can spread through the body. As this detrimental build-up forms large growths, they cause extreme problems and limit the function of vital organs.

Today's technology allows medical professionals to see the cellular activity within a patient's body in the form of a computerised image. Being able to spot trends in cancerous growths, and know where the cells are located, plays an essential role in saving lives.

> *"The cells of a tumour can be targeted and destroyed"*

Nuclear medicine is a method of treating cancer by introducing controlled volumes of radioactive substances to the body. Using trace amounts of certain substances, the cells of a tumour can be targeted and destroyed, shrinking the tumour without impacting healthy cells too much. The therapy brings together powerful radiation and the skills of laboratory researchers to create substances that mimic the cells in our body.

Although it's not enough to completely eliminate cancer from the body by itself, this method has proven successful in controlling the growth, and in some cases can rid the body of cancer when combined with other therapies.

5 NUCLEAR MEDICINE SCANS

1 Bone
After being injected with radionuclides, the patient has to allow about two hours for the radiation to circulate the body and reach the bones. The scan shows larger volumes of radiation where a tumour is breaking down bone.

2 Gallium
This can be used to show where cancer cells are dividing quickest in the body. It is released into the body from an intravenous drip, also highlighting areas of inflammation and infection.

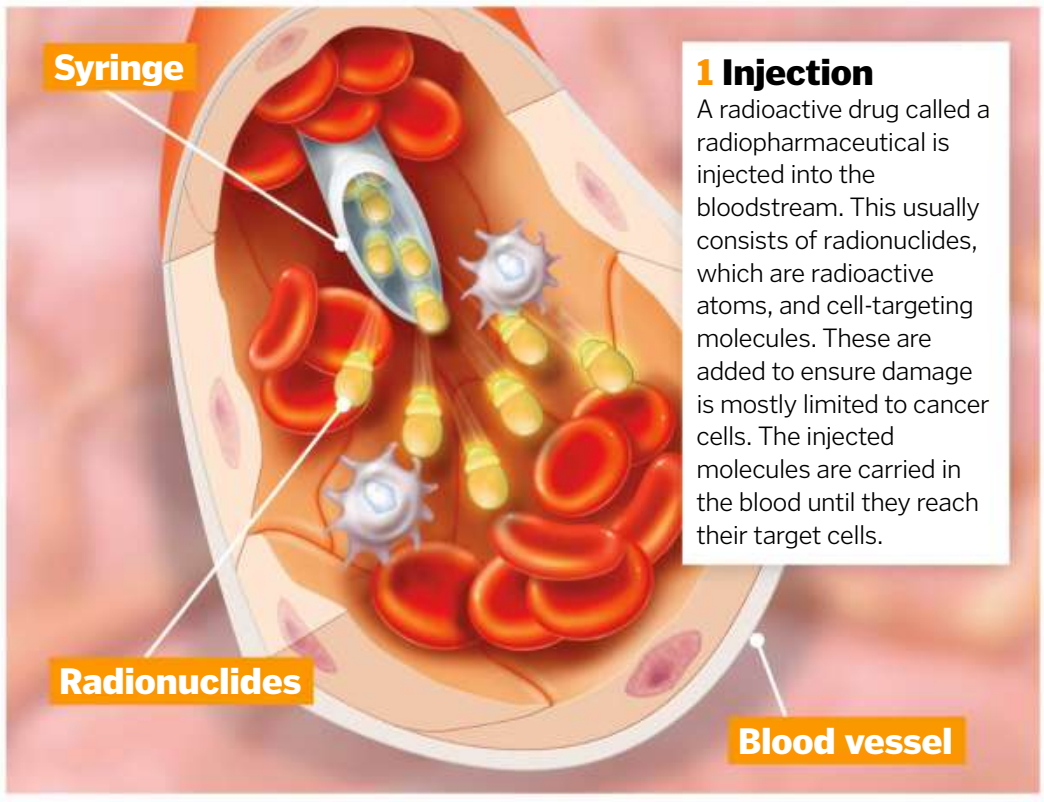
3 MUGA scan
A multigated acquisition scan uses radionuclides to bind to red blood cells, acting like a dye to highlight the blood's movement. Doctors can monitor the impact of chemotherapy on a patient's heart, tracking how it pumps blood.

4 PET scan
Positron emission tomography scans are all about displaying a tumour's activity. By injecting radioactive sugar into the body and analysing the rate and location of cell absorption, the scan can display the rate of tumour growth as well as the location.

5 Thyroid
Radioiodine scans can be used to detect abnormalities in the thyroid. The iodine is either injected or swallowed. Over the next hour to several days, the thyroid will absorb the iodine. A camera placed in front of the patient's thyroid detects radioactive levels in different areas. Areas that have absorbed little or no iodine could indicate the presence of cancer cells.

How targeted radionuclide therapy works

Radioactive substances injected into the bloodstream can destroy cancerous cells



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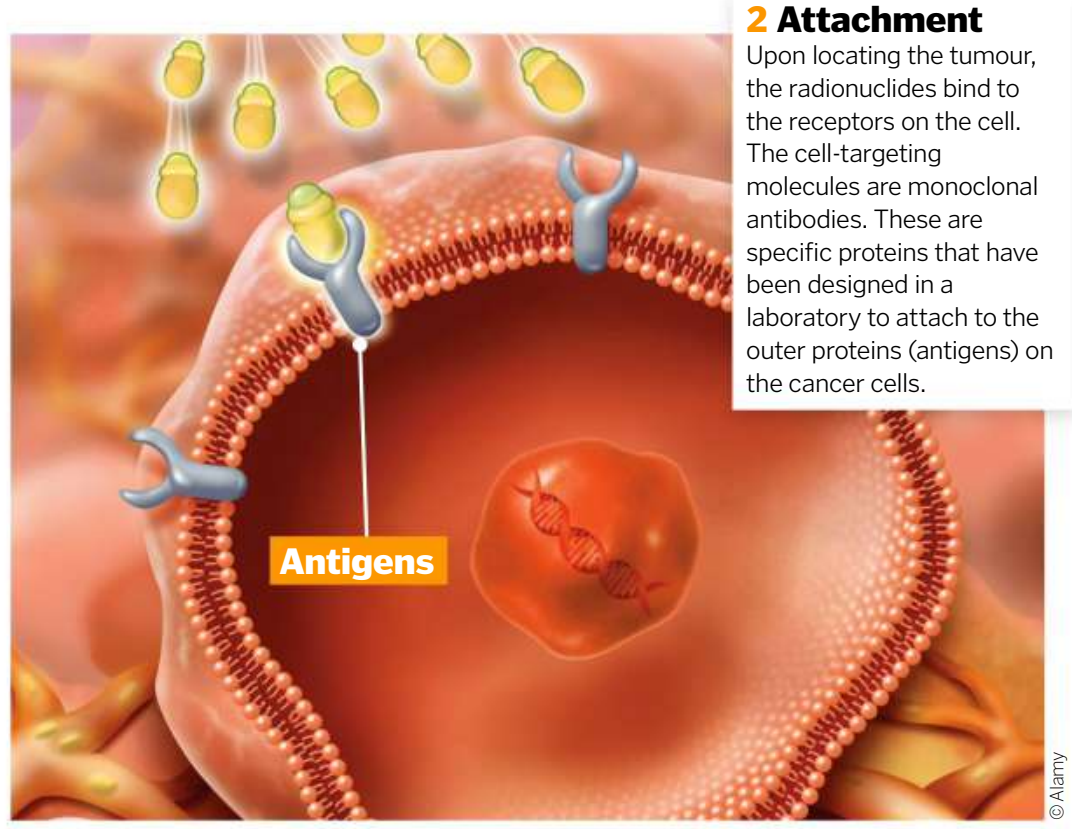
1 Injection

A radioactive drug called a radiopharmaceutical is injected into the bloodstream. This usually consists of radionuclides, which are radioactive atoms, and cell-targeting molecules. These are added to ensure damage is mostly limited to cancer cells. The injected molecules are carried in the blood until they reach their target cells.



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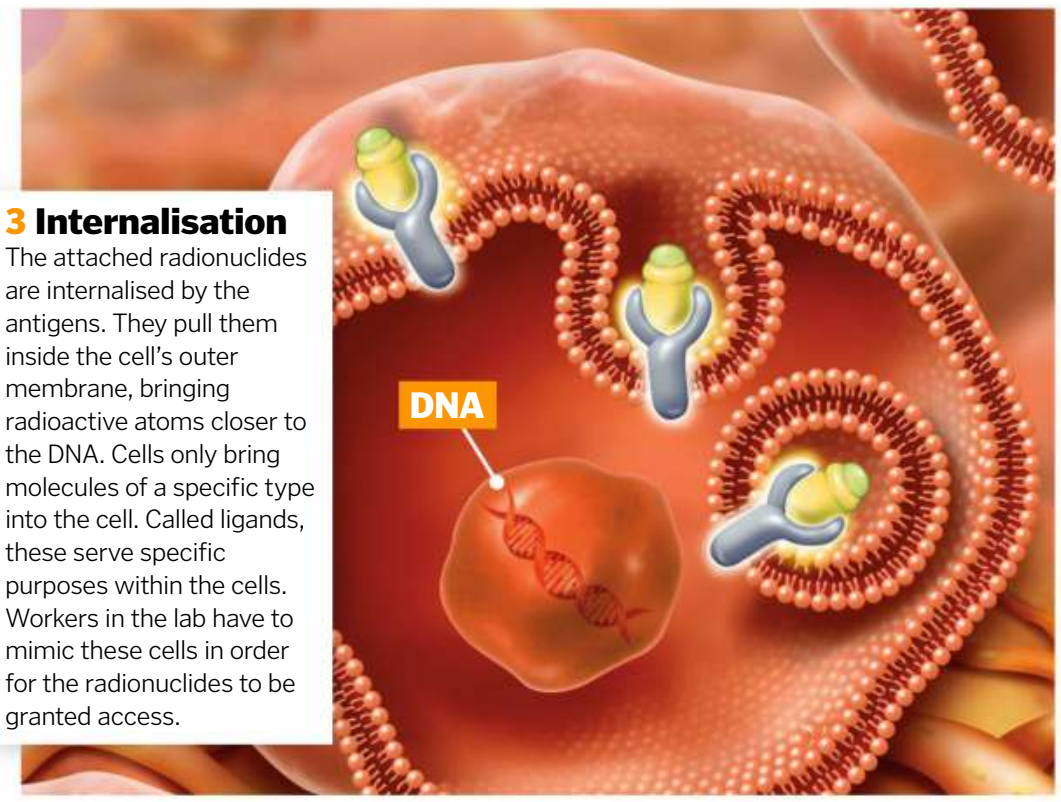
2 Attachment

Upon locating the tumour, the radionuclides bind to the receptors on the cell. The cell-targeting molecules are monoclonal antibodies. These are specific proteins that have been designed in a laboratory to attach to the outer proteins (antigens) on the cancer cells.



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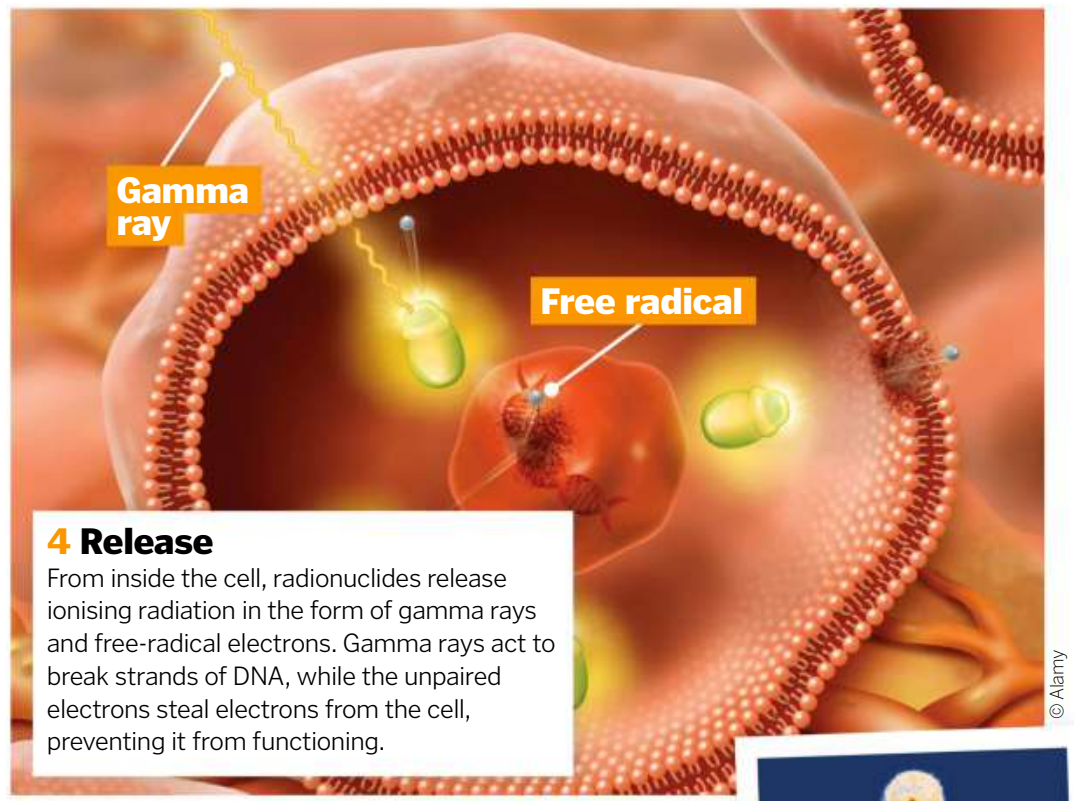
3 Internalisation

The attached radionuclides are internalised by the antigens. They pull them inside the cell's outer membrane, bringing radioactive atoms closer to the DNA. Cells only bring molecules of a specific type into the cell. Called ligands, these serve specific purposes within the cells. Workers in the lab have to mimic these cells in order for the radionuclides to be granted access.



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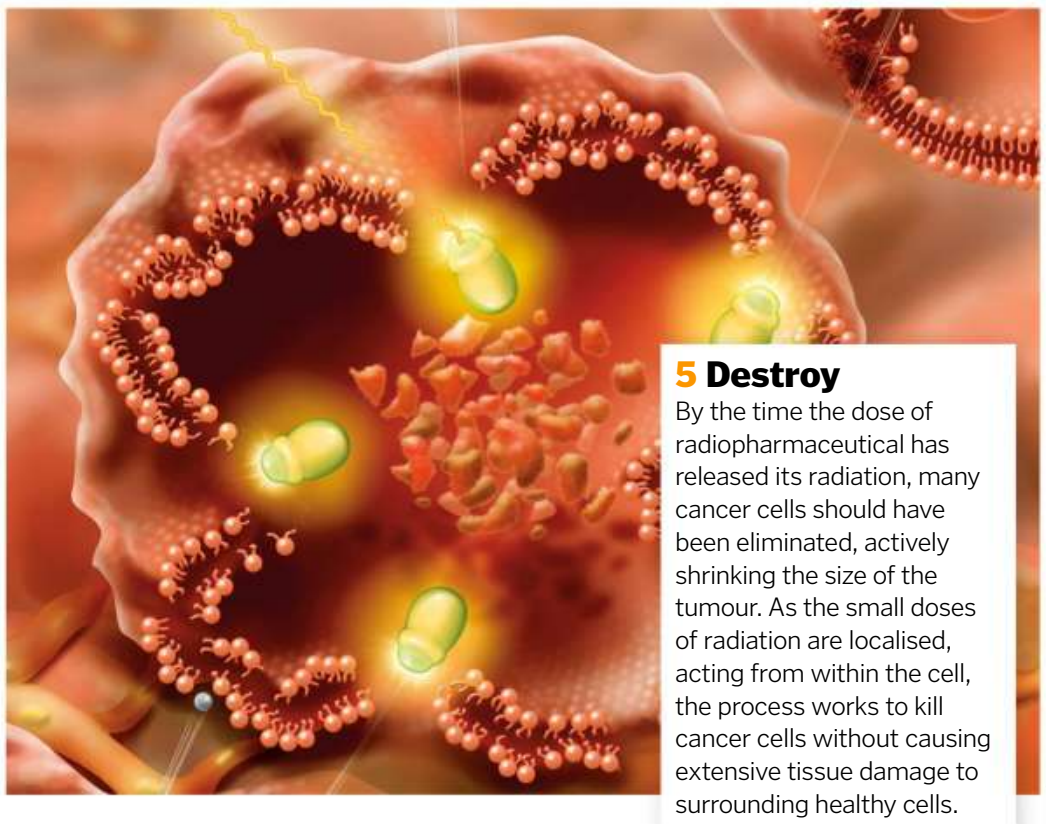
4 Release

From inside the cell, radionuclides release ionising radiation in the form of gamma rays and free-radical electrons. Gamma rays act to break strands of DNA, while the unpaired electrons steal electrons from the cell, preventing it from functioning.



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5 Destroy

By the time the dose of radiopharmaceutical has released its radiation, many cancer cells should have been eliminated, actively shrinking the size of the tumour. As the small doses of radiation are localised, acting from within the cell, the process works to kill cancer cells without causing extensive tissue damage to surrounding healthy cells.

Detecting 'hotspots'

The end result of most nuclear medicine tests is an image, arranging the data into a visual format that doctors can easily recognise and evaluate. As radionuclides and other radioactive sources release gamma rays into the body, the presence of this radiation is recorded. During the scan, gamma cameras convert any concentrations of radionuclides they detect into a picture, revealing the areas targeted by the radionuclides and flagging up any hotspots.

Hotspots are areas where these atoms have congregated and where the most damaging tumours are likely to be found. Often colour-coded to display intensity ranges, a series of these scans can show changes in the activity of cancerous cells and spot new growths before they become any larger.

© Getty

This nuclear medicine scan shows osteosarcoma of the knee

Life from other worlds

Could life have been brought to Earth by meteorites, space dust or even aliens?

Words by **Ailsa Harvey**

How life originated on Earth is one of the most fundamental problems ever to puzzle scientists. The world we know is teeming with remarkable species. It's the existence of these living things that separates our planet from all the other worlds we've discovered and explored. Earth's ability to support life has created diverse ecosystems and brought us all into existence. But its origin happens to be one of the longest standing debates in scientific history.

Panspermia is the name of one popular theory, stating that life isn't confined to just one planet. It didn't necessarily originate on Earth, and it can be transported and spread throughout space. Although the theory involves some wild claims that border on science fiction, others are based on fragments of solid scientific evidence.

The most plausible of this theory's explanations for the interplanetary distribution of life, is that bacterial colonies were transported from one planet to the next. Evidence of microbial life within meteorites on Earth may indicate that this transportation was made possible by material dislodged from other bodies that then travelled on its own trajectory through space. If this is the case, is our world a one-off, produced by chance, or could microbes have created a series of Earth-like homes on numerous planets throughout the universe?

Some versions of the panspermia theory are becoming closer to being either proven or dismissed. As we explore the universe that surrounds our home planet, our evolving knowledge and technology are allowing us to venture farther afield and investigate more thoroughly. In some instances, signs of life are being detected on planets that we once thought were lifeless. But it's only when we understand the definition of life more thoroughly that we can begin to truly understand where it came from, along with our own existence.

Extremophile bacteria are able to grow in conditions that are considered challenging for carbon-based life forms

© Science Photo Library

5 signs of life beyond Earth

1 Viking lander experiments

In 1976, NASA's Viking landers began their trawl of Mars, hunting for signs of life. During one of the experiments, the landers detected chemical activity in the soil that indicated methane production – a potential biosignature. They also found the five elements essential for life on Earth.

2 Determining probability

A study in 2001 estimated that there are hundreds of thousands of life-bearing planets in the galaxy and that the nearest Earth-like planet could exist just a few hundred light years away. This probability can be calculated by analysing the number of possible life-supporting planets and applying this calculation to unexplored regions. Spacecraft such as NASA's Kepler show that around one-fifth of stars have habitable zones where temperatures could support life.

3 Alien potential

Scientists have been scanning space for alien transmissions for the last 60 years, occasionally detecting unexplained signals. In 2020, astronomers recorded mysterious radio signals from the direction of Proxima Centauri, the Sun's closest star. There are two planets known to orbit this star, and one is thought to be temperate and rocky.

4 Sulphur on Europa

When sulphur traces were found on Jupiter's moon Europa during NASA's Galileo mission, some scientists believed it could be a sign of life there. The sulphur looked like the waste product of bacteria that had risen to the surface. Others believed it had merely come from another of the planet's moons, Io, where sulphur is produced in high volumes by volcanoes.

5 Phosphine on Venus

When the discovery of phosphine gas in the clouds of Venus was announced in September 2020, there was reportedly more than 1,000 times the amount of this gas than found on Earth. Being a rocky planet like Earth, Venus wasn't believed to be able to produce phosphine without life: on Earth, microbes make the gas. Scientists haven't ruled out the possibility that it's produced by a non-living source.

The three variations

What are the main hypotheses for panspermia?

© Getty

Directed panspermia

Some believe that life didn't just reach Earth from other planets, but was sent here by a more advanced species. Could there be another human-like species out there – or perhaps a more intelligent one – that has created life as we know it?

© Getty

Ballistic panspermia

This theory of interplanetary transfer involves rock from other planets being dislodged and flying through space towards Earth. This specific theory focuses only on planets within our Solar System.

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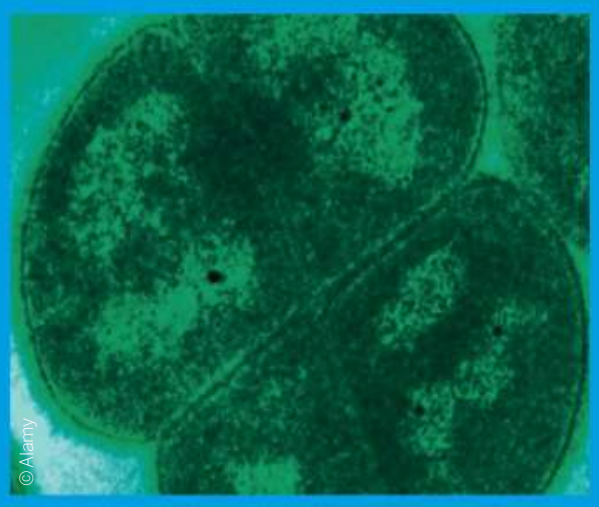
Lithopanspermia

Similar to ballistic panspermia, but looking much further afield, this theory states that the biological matter that developed into life on Earth travelled from beyond our Solar System through interstellar space.

Can bacteria survive in space?



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D. radiodurans can withstand radiation, dehydration, vacuum exposure and acidity

If life on Earth was seeded from other worlds in the form of bacteria, these microorganisms would need to survive in space for significant periods of time. In May 2015, an experiment was launched by researchers from the University of Tokyo and the Japan Aerospace Exploration Agency, which would prove this was possible for at least one species.

Colonies of *Deinococcus radiodurans* bacteria were placed on the outside of the International Space Station and monitored over the course of three years to see if they would survive. The bottom layer of bacteria returned to Earth alive, having been protected by the dead cells covering them. While not all microorganisms can survive the journey between planets, there is still potential for some. This research has helped to keep the theory of panspermia alive.

AR ZONE!

Could life have come from Mars?

This Martian meteorite holds potential evidence of microbial life on the Red Planet

In 1984, the ALH84001 meteorite was discovered in the Allan Hills region of Antarctica. But it wasn't until 1996 that this lump of rock would gain significance, being used to build upon evidence of panspermia. A group of scientists, led by David McKay from NASA's Johnson Space Flight Center, declared that their research showed signs of Martian life within the meteorite.

At 4 billion years old, this meteorite is thought to have existed on Mars during a period when the planet was abundant in water, an essential resource for life. Scientists looked at the centre of the rock to avoid using sections contaminated by the environment on Earth.

Sceptics fought the evidence, with the view that the patterns and materials within the meteorite could have been formed from non-biological processes. Since then, it's been discovered that minerals from within the rock, such as magnetite, have the potential to be formed from shock waves and not just microbial life. The interpretation of this meteorite is still debated by scientists today, but neither argument can be ruled out as impossible.

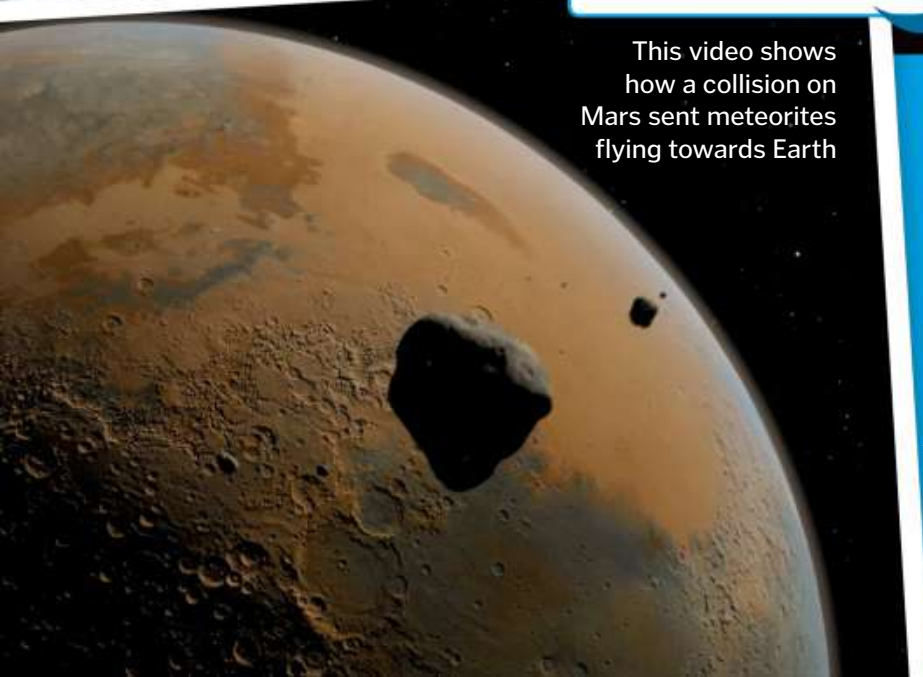
© Getty

Into orbit
The two-kilogram fragment of Mars would have entered into orbit around the Sun before coming into contact with Earth.

Impact zone
A great impact would have been needed to dislodge the rock from Mars and send it travelling at speeds of over three miles per second in order for it to escape Mars' gravity.

Magma rock
The meteorite is believed to have formed from crystallised magma 4 billion years ago.

AR ZONE! SCAN HERE



This video shows how a collision on Mars sent meteorites flying towards Earth

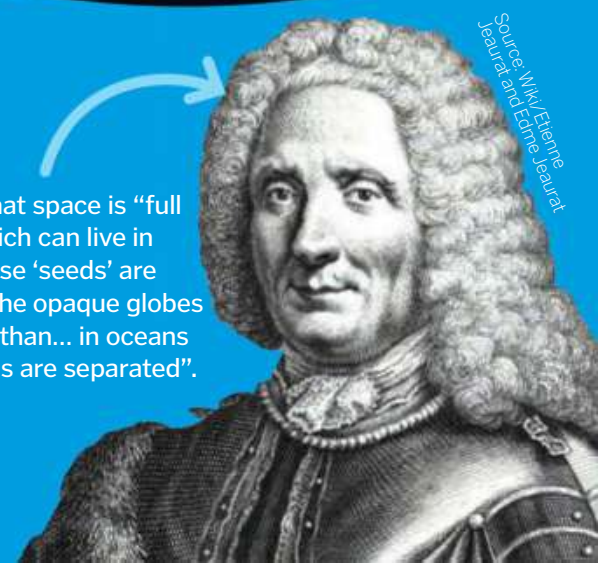
© Getty

Theory development

How have philosophers and scientists shaped the evolution of this theory?

500 to 428 BCE
The theory originates from pre-Socratic Greek philosophy. Philosopher Anaxagoras of Clazomenae mentions 'seeds' twice as part of his work on the origin of the cosmos.

1700s
Benoît de Maillet writes that space is "full of seeds of everything which can live in the universe" and that these 'seeds' are "more numerous around the opaque globes in thick airs and in waters than... in oceans of void by which the globes are separated".



Source: Wiki/Etienne Jeaurat and Edme Jeaurat

Landing area
Coming into contact with Earth, ALH84001 landed in Antarctica 13,000 years ago.

The bacteria for the Tanpopo mission were exposed to space on the Japanese Kibo module of the ISS

© NASA

Meteorite composition
Scientists found that the rock contained tiny grains of iron sulphide and magnetite. These are rarely found together with carbonates unless produced by bacteria. Their microscopic size fitted this theory.

Fossilised bacterium
The long, rounded shape matches the fossilised shapes of microorganisms.

© Getty

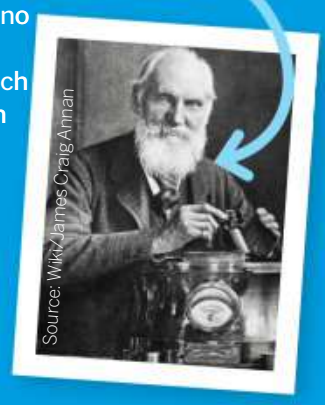
1800s
The Kant-Laplace nebular hypothesis emerges, which states that the Solar System was formed from a nebula. If Earth was originally too hot for life, it must have appeared on a previously lifeless planet.

© Getty

1859
Darwin's theory of evolution makes people consider a point of origin for all life. For some, this point is envisaged far from our planet.

1865
Hermann Richter, a German physician, becomes the first person to define the theory, giving it the name panspermia.

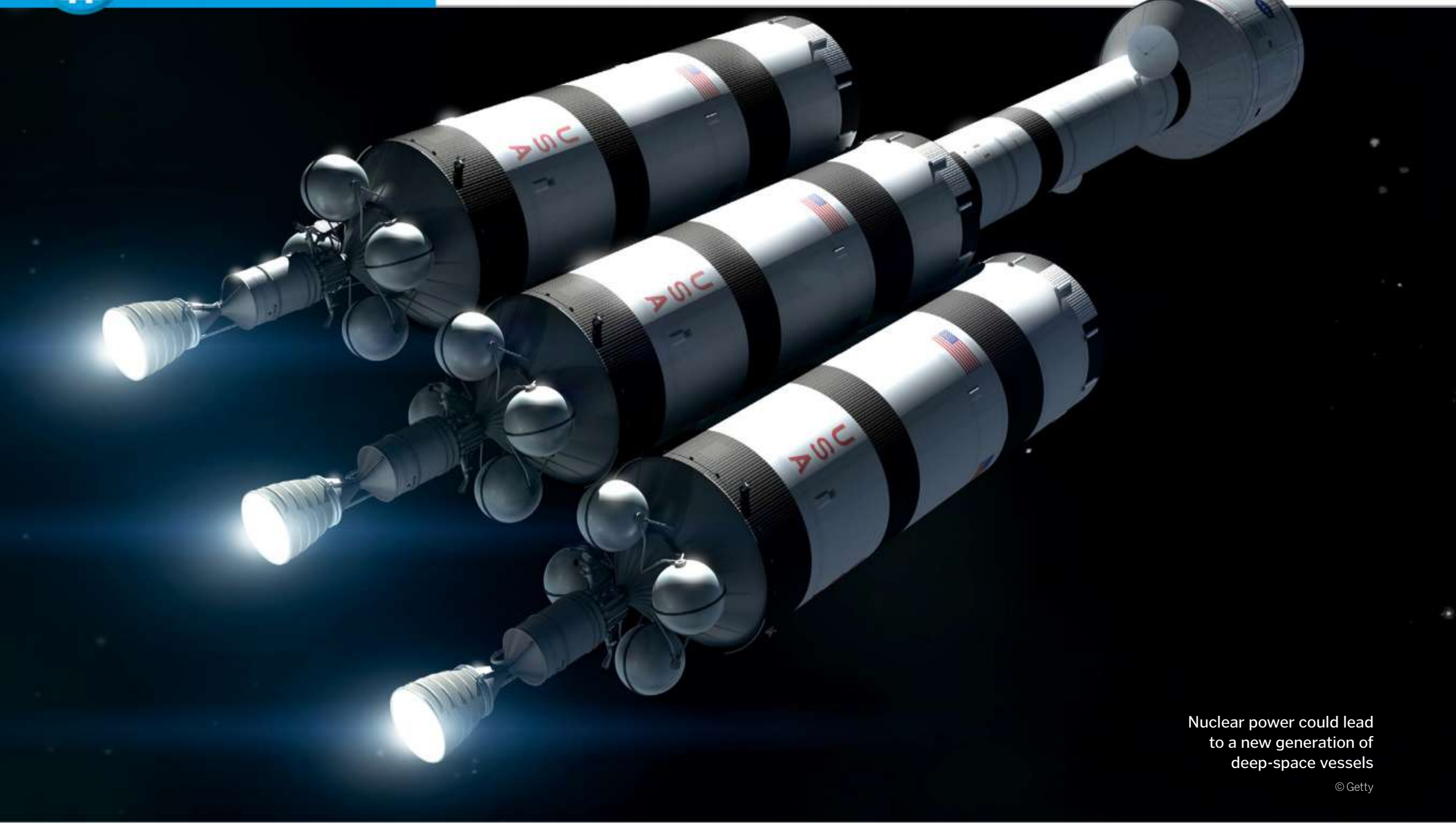
1871
Sir William Thomson claims "there are countless seed-bearing meteoric stones moving about through space. If at the present instance no life existed upon this Earth, one such stone falling upon it might... lead to its becoming covered with vegetation".



Source: Wiki/James Craig Annan

1908
Svante Arrhenius, a Nobel Prize-winning Swedish scientist, isn't convinced that life travelled through space on solid objects. Instead he suggests that microbes could be transported through space by solar radiation.

1938
The first fully formed theory of how life could have grown from non-life through chemical evolution on Earth is written by biochemist Alexander Oparin. Many scientists don't consider it plausible, and instead keep the theory of panspermia alive.



Nuclear power could lead to a new generation of deep-space vessels

© Getty

Nuclear spacecraft to Mars

Could nuclear power be the answer to deep-space missions?

Space vehicles have traditionally been fuelled by chemicals, but such fuel has to be carried in bulky tanks, which are cumbersome and not always efficient. Technology such as solar panels can provide a source of power for satellites and space stations, but the Sun's energy is not strong enough to power craft that venture further from its glow and head into the deepest recesses of the Solar System. A new era of cosmic exploration could be on the horizon after a British study was launched into nuclear-powered space travel.

Experts from the UK Space Agency and Rolls-Royce are teaming up to find out whether atomic engines could provide the solution to both problems. Nuclear propulsion would involve channelling the energy released by splitting the atom to accelerate propellants such as hydrogen. This would be done at huge speeds to propel a spacecraft for extremely long durations and distances. Some experts think such an engine could be twice as efficient as the chemical engines that power the current generation of rockets.

The idea has existed since the 1950s, and was studied extensively as part of the Nuclear Engine for Rocket Vehicle Application (NERVA) program. US scientists on the program had originally hoped to reach Mars by 1978 and establish a base there by 1981, with deep-space exploration to Jupiter and Saturn set to follow. But the project was axed in 1973 following years of political wrangling in the US government over cost concerns. Now, by reviving the research, British scientists hope to turn the original dream into modern reality.

Mission to Mars

With the Moon conquered in 1969, Mars has long been the dream destination of generations of astronauts. A mission to Mars powered by a nuclear engine could in theory reach the Red Planet in between three and four months – roughly half the time it takes an uncrewed spacecraft using current technologies. The main reason that cutting the travel time is so important is that as humans leave the protection of Earth's magnetosphere, they are bombarded by harmful cosmic radiation. And although special shielding can provide some protection, it adds to the weight of the spacecraft, making a journey even longer.

Nuclear engines could pave the way for a crewed mission to Mars

© Getty

A history of nuclear engines

The NERVA project may have been the most famous exploration of atomic engines undertaken so far, but it is by no means the only such endeavour. In 2003 NASA's Project Prometheus was set up to once again look at the use of nuclear-powered propulsion. If successful, the plan would have been to develop a spacecraft that could voyage to Jupiter's moons.

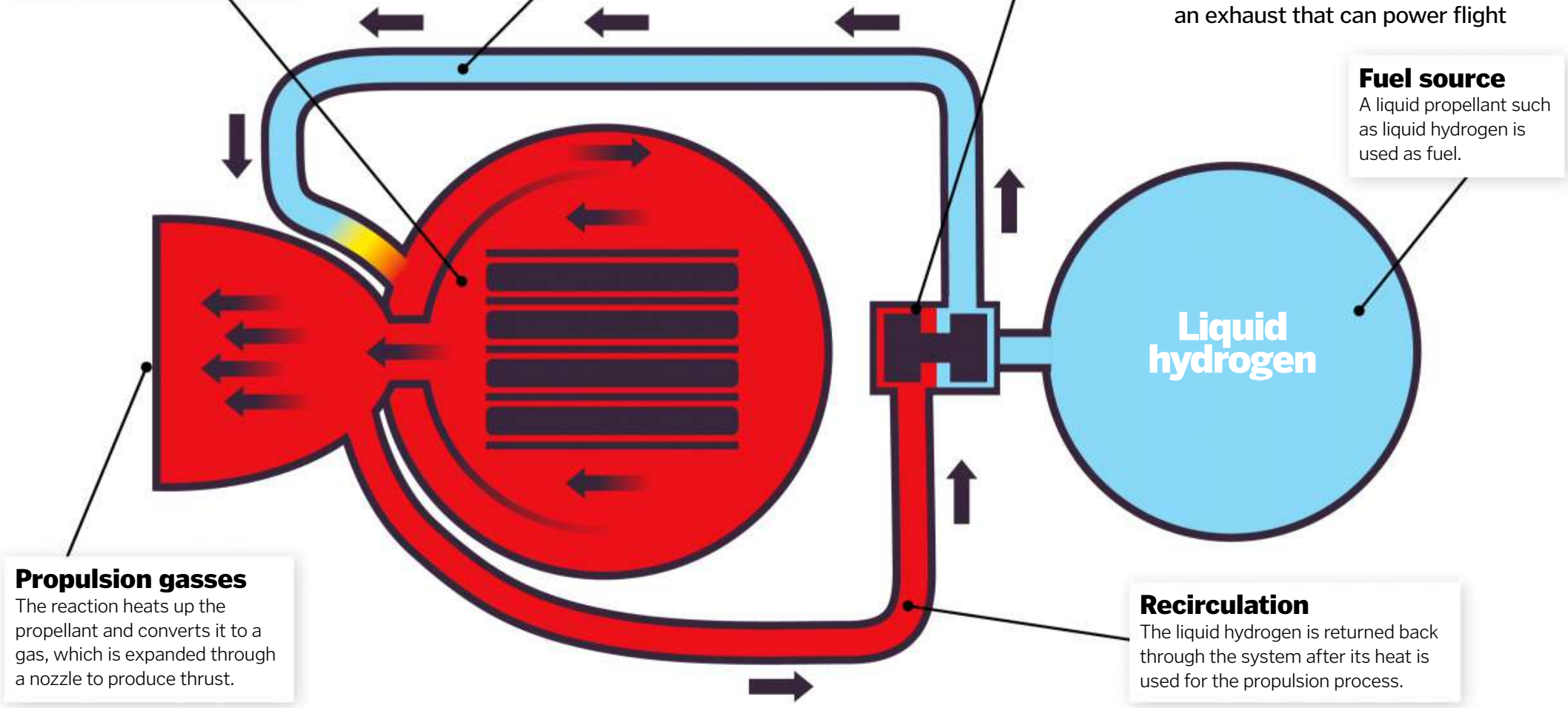
Although that project did not take off, NASA is still exploring nuclear thermal propulsion (NTP) along with a number of companies in the US. One such company is Seattle-based Ultra Safe Nuclear Corporation (USNC), which has developed a concept for a new NTP engine which it claims is safer and more reliable than previous designs. The company's new technology centres on a type of fuel called Fully Ceramic Microencapsulated (FCM), which the company says is much more rugged than conventional nuclear fuels and can operate at high temperatures.

The NERVA project helped pave the way for nuclear-powered engine research

© NASA

How a nuclear engine works

Using an atomic reaction to create an exhaust that can power flight


Nuclear reaction
Uranium atoms split apart inside the core, releasing heat through the process of nuclear fission.
Power pump
The pump ensures a steady flow of liquid hydrogen through the engine.
Beating heart
A turbine pump propels the fuel into the reactor.
Fuel source
A liquid propellant such as liquid hydrogen is used as fuel.
Liquid hydrogen
Propulsion gasses
The reaction heats up the propellant and converts it to a gas, which is expanded through a nozzle to produce thrust.
Recirculation
The liquid hydrogen is returned back through the system after its heat is used for the propulsion process.

50x
There's far more energy in a can-sized amount of plutonium than in a Space Shuttle's fuel tank

900 seconds
The impulse of a rocket that combusts liquid hydrogen

2,430°C
The temperature liquid hydrogen is heated to in the reaction

50%
The amount of time atomic engines can take off a journey to Mars

A mission to Mars could take between 10 and 30 years to plan and carry out

20
The number of years an atomic engine might have to last without maintenance

NTP systems won't be used on Earth. Instead they'll be launched into space by chemical rockets

Ten months
Travel time to Neptune with an atomic space engine

Sunken cities

Explore these submerged settlements to discover why they didn't survive the test of time

Words by **Nikole Robinson**

Humans need water to survive, and so access to this precious natural resource has been an important factor in deciding where we have made our homes throughout history. Building near rivers, lakes and springs gave early settlements access to clean water for domestic and agricultural use, and the availability of fish was a reliable food source. Travelling by boat also became an easy way to navigate the land more quickly, allowing our species to migrate to new areas. As humans spread across continents and populations boomed, trade between civilisations became more frequent. Coastal settlements allowed for larger vessels to come and go, increasing trade and therefore the local economy, with many more port towns being built as a way to access rare goods and riches.

But the waterfront isn't always a safe place to settle. With little protection from flooding, natural disasters such as earthquakes and tsunamis, bad weather and changing sea levels can all easily destroy in a day what has taken people hundreds of years to build. Water can claim the land, buildings and human lives. Here we dive into some of the lost civilisations now deluged beneath the depths.

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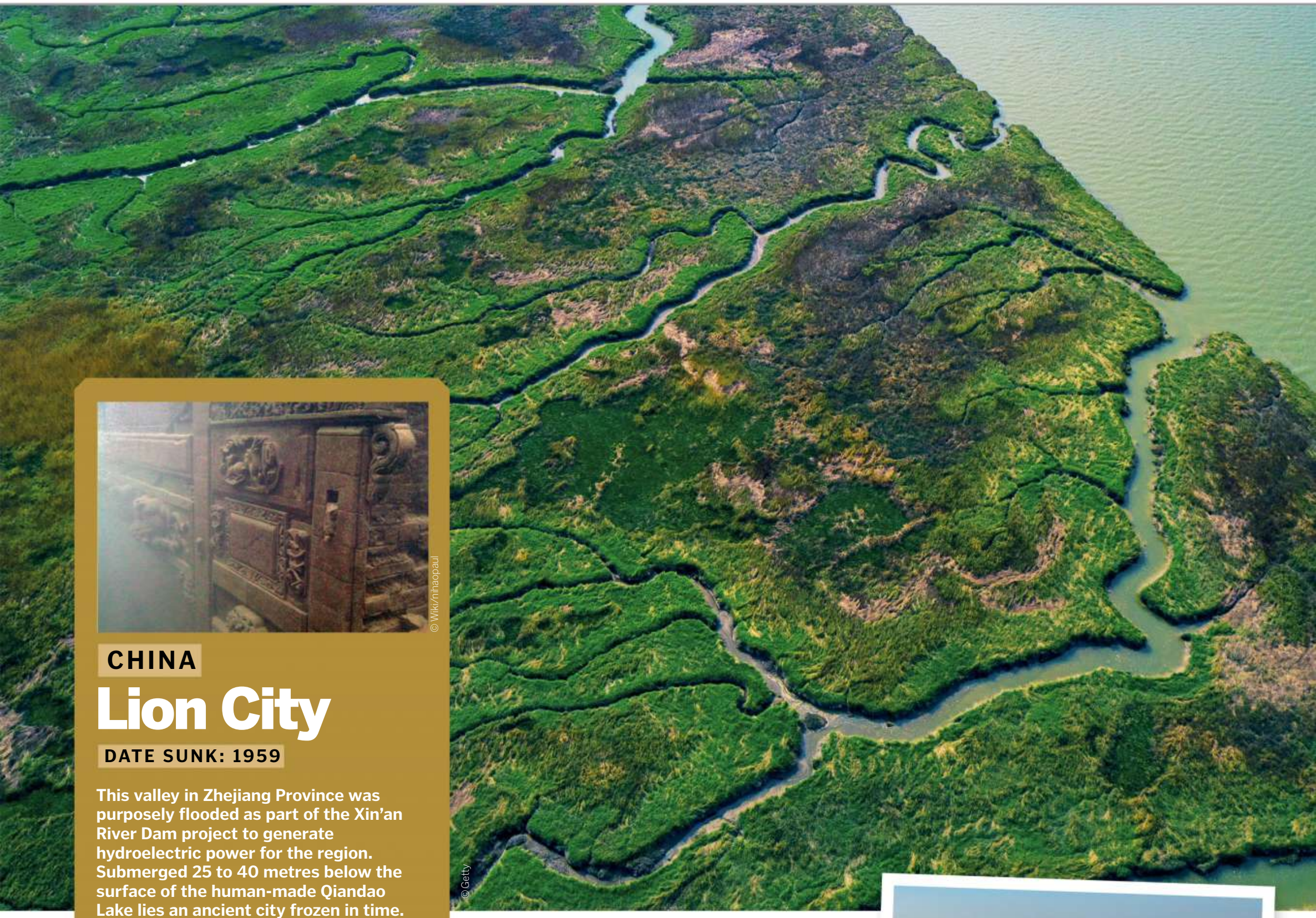

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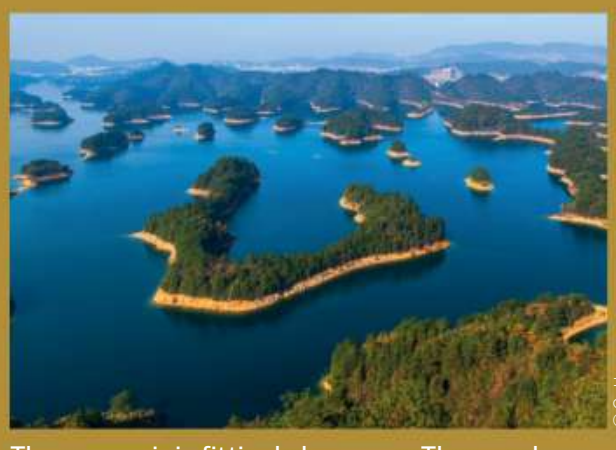
CHINA

Lion City

DATE SUNK: 1959

This valley in Zhejiang Province was purposely flooded as part of the Xin'an River Dam project to generate hydroelectric power for the region. Submerged 25 to 40 metres below the surface of the human-made Qiandao Lake lies an ancient city frozen in time. Believed to be around 1,400 years old – though some believe certain structures are even older – the city once stood at the bottom of Wu Shi (Five Lion) Mountain, which is now also partially submerged. Rediscovered in 2001 on a diving excursion, the city is a well-preserved relic of its time, with many intricate carvings of dragons, phoenixes and lions surviving in all their glory on wooden arches. Temples, pagodas and other structures remain intact thanks to the purity of the water, allowing archaeologists a window into the architectural design of ancient China.



© Getty

The reservoir is fittingly known as Thousand Island Lake

© Getty

THE NETHERLANDS

Saeftinghe

DATE SUNK: 1584

Now a swamp known as the Drowned Land of Saeftinghe, this was once a prosperous place. In the 13th century the marsh was drained so that the fertile land could be built on, and dikes were raised around the reclaimed land to protect it from floods. Much of the land around Saeftinghe was lost in the All Saints' Flood of 1570, but the final blow came during the Eighty Years' War in 1584. Dutch soldiers fighting in the war for independence were forced to destroy the last dike barrier while defending Antwerp, allowing the waters of the Scheldt to take over the town. A local legend tells a slightly different tale, however, blaming the 1570 flood on the wrath of a mermaid held captive by the townsfolk. Today the settlement is buried under layers of sand and clay, though bricks have been recovered that could have belonged to an abbey taken by floods.

All that remains of Saeftinghe is marshland, frequently covered by tumultuous tides

© Alamy

"Dikes were raised around the reclaimed land to protect it from floods"

AR ZONE!

JAMAICA

Port Royal

DATE SUNK: 7 JUNE 1692

The Caribbean pirate haven of Port Royal was known as 'the wickedest city on Earth' before a devastating earthquake and the tsunami that followed in its wake cast two-thirds of the town below the waves. The intense shaking liquified the sand beneath the 2,000 or so brick buildings, which were displaced and appeared to flow out to sea. Of the estimated 6,500 inhabitants of the town at the time of the disaster, 2,000 are thought to have perished in the earthquake and tsunami. A further 3,000 were to meet their end from injuries and disease in the aftermath.

Artist Jan Luyken's impression of the disaster

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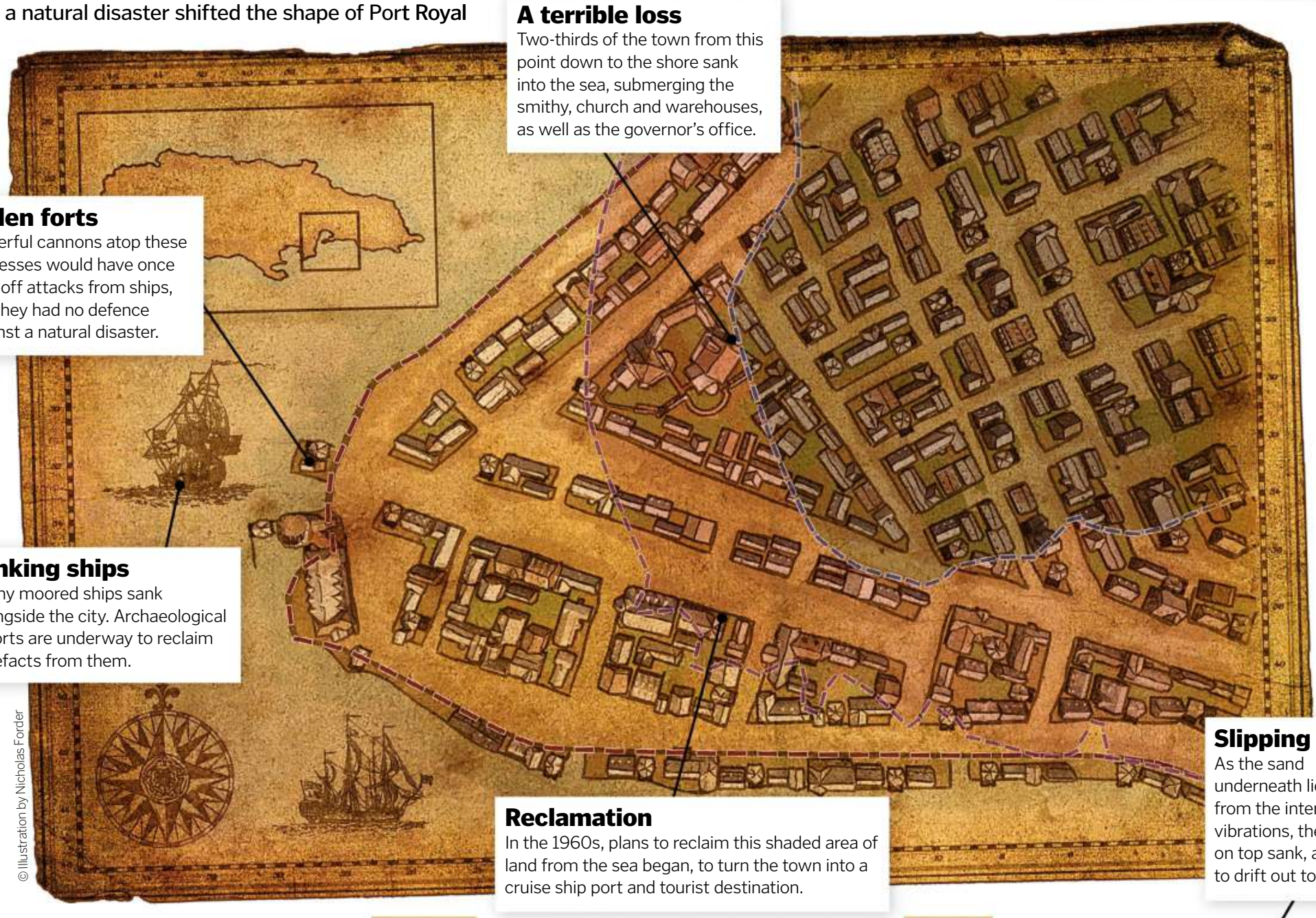
Changing shorelines

How a natural disaster shifted the shape of Port Royal



A terrible loss
Two-thirds of the town from this point down to the shore sank into the sea, submerging the smithy, church and warehouses, as well as the governor's office.

Fallen forts
Powerful cannons atop these fortresses would have once held off attacks from ships, but they had no defence against a natural disaster.

Sinking ships
Many moored ships sank alongside the city. Archaeological efforts are underway to reclaim artefacts from them.

Reclamation
In the 1960s, plans to reclaim this shaded area of land from the sea began, to turn the town into a cruise ship port and tourist destination.

Slipping sand
As the sand underneath liquified from the intense vibrations, the buildings on top sank, appearing to drift out to sea.

© Illustration by Nicholas Forder

AR ZONE! SCAN HERE

GERMANY

Rungholt

DATE SUNK: 16 JANUARY 1362

Long considered to be just a legend, the exact location of Rungholt remains unclear, though artefacts have been found in the Wadden Sea that hint at its existence as a trading port. Saint Marcellus' flood, also known as the 'Great Drowning of Men', is thought to be the culprit behind the town's disappearance. Storm tides caused by an extratropical cyclone swept in from the North Sea, decimating the coasts of the British Isles, the Netherlands, northern Germany and Denmark and causing deaths in thousands.

The area suspected to have hosted Rungholt is mostly salt flats now

© Getty

An ancient stone semi-circle was uncovered at the site

© Wiki/Hanay

ISRAEL

Atlit Yam

DATE SUNK: 6300 BCE

This Neolithic village lies 8 to 12 metres beneath the Mediterranean, hidden for over 8,000 years until marine archaeologist Ehud Galili was surveying the sand for shipwrecks in 1984.

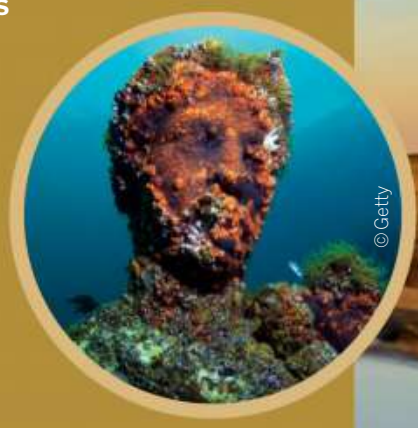
One of the oldest submerged settlements ever discovered, careful excavations have revealed rectangular houses with hearths and the remains of a dry-stone well. One of the most interesting finds was a megalith structure – similar to Stonehenge – built around a spring, made of seven huge stones weighing around 600 kilograms each, while burial sites and human remains have also been unearthed. One study suggests that a tsunami is likely to blame for the abandonment of the settlement.

ITALY

Baiae

DATE SUNK: 16TH CENTURY

Once a Roman spa town known for debauchery, underground pressure causes the land in the area to rise and fall, and much of its ancient history lies just six metres below sea level. Of note are the underwater remains of the Pisonian Villa and the statue-adorned Sunken Nymphaeum of Emperor Claudius.



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GREECE

Pavlopetri

DATE SUNK: 1000 BCE

Uncovered in 1967, analyses of building materials date these ruins to be around 5,000 years old. Existing above ground for 2,000 years before it was likely sunk by earthquakes, the layout of the town has been preserved perfectly four metres below the waves, with its streets, buildings and tombs eroded by age but clear to see – at least 15 buildings have been identified.

© Alamy

EGYPT

Thonis-Heracleion

DATE SUNK: 6TH OR 7TH CENTURY CE

Northwest of Alexandria on the Nile Delta, this was a popular trading port before tremors weakened the land and dragged it below the brine. A giant six-tonne statue of the Nile god Hapy is one of the most significant finds from the ruins.

© Alamy

TITANIC
The most famous wreck in the world is deteriorating at the bottom of the Atlantic after its fateful meeting with an iceberg over 100 years ago.

DOLCHISTE
On the northern side of the Turkish island of Kekova, the partially submerged ruins of this town are often visited by boat tours.

LAKE MICHIGAN
Shipwreck searches turned up a stone carving of a mastodon and a Stonehenge-like structure about 12 metres below the surface of this Great Lake.

DUNWICH
Now a quaint village in Suffolk, England, in Anglo-Saxon times this was a major trading port before it was destroyed by storms.

GRÜNER SEE
Green Lake floods every year due to snowmelt from the Hochschwab Mountains, becoming a popular spot for divers due to the surreal experience.

CENOTE ANGELITA
This cave has an 'underwater river'. This eerie effect is created by hydrogen sulphide released from organic matter separating the fresh and saltwater.

APOLLO 11
In 2013, Jeff Bezos spearheaded an expedition to retrieve parts of the Saturn V rocket that launched astronauts to the Moon from the seafloor.

NEAPOLIS
A massive storm in 2013 revealed strange stone shapes in the seabed. They were identified as a Roman port town, Neapolis, sunk by an earthquake in 365 CE.

Submerged secrets

There are many interesting things hidden under the water around the world

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DID YOU KNOW? *The USS Johnston is the deepest known shipwreck, lying 6,217 metres below the sea*

© Getty

YONAGUMI MONUMENT

Some think that this is a 5,000-year-old city that sunk around 2,000 years ago, while others debate that it's a natural structure.

5 FACTS ABOUT UNDERWATER ODDITIES

1 A window below
Glass-bottom boat tours are popular in Pavlopetri, Greece.

2 From pirates to cruises
The first cruise ship in over 40 years docked at Port Royal in January 2020.

3 Taller than Everest
Mauna Kea is the tallest mountain at 10,211 metres, but more than half is below sea level.

4 Sunken treasure
The San José galleon wreck holds treasures worth billions.

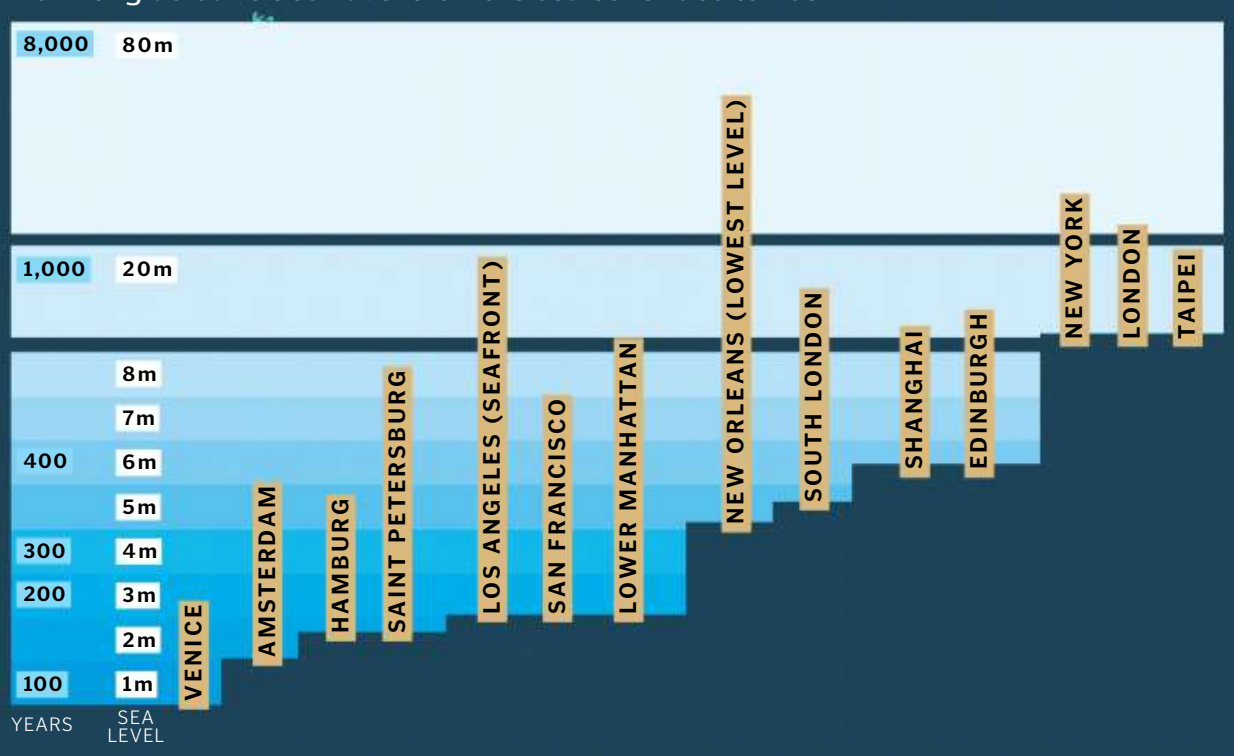
5 Sea level rise
Average sea levels have risen 23 centimetres since 1880.

LOST CONTINENT

The continent of Zealandia is mostly submerged in the South Pacific. Ball's Pyramid is one natural structure that breaches the surface.

The threat of rising tides

How long do our cities have left if the sea continues to rise?



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How to excavate an archaeological site

These experts use patience, precision and problem-solving to retrieve history from the ground

The remains of ancient cities, people and their belongings are of great importance to historians. They can provide information about our ancestors and tell us how human behaviour has changed over time. Often the position of artefacts, along with their location and surroundings, can allow the experts who excavate these sites – called archaeologists – to put the pieces together to discover the items' stories. Trained to know what to look for, these professionals know how to uncover historic treasures while limiting any damage. Large groups of experts work together on a dig to analyse every grain of soil in the plot. But what steps do they need to take when unearthing a historically valuable site?

© Alamy

The two main types of archaeology are historic and prehistoric, with the latter looking for clues about undocumented history

Uncovering history

Follow the eight essential steps for excavation

© Getty

1 Survey the site

Before digging, archaeologists record data about the area. Using tools called dumpy levels, they measure the height of the land in relation to a fixed point. Using electromagnetic radiation, ground-penetrating radars can detect artefacts up to 15 metres below the surface, informing members of the team about where to dig.

© Alamy

2 Make a grid

Sectioning the dig site into smaller squares makes it easier to record where each item was discovered and which objects were found together. Recording the position of artefacts in a grid is important for later analysis. Long measuring tapes are often used in order to measure these squares evenly and accurately.

© Getty

3 Dig the topsoil

Digging is methodically executed. First the topsoil is explored. Using the side of a trowel, earth is evenly scraped away. Larger objects embedded deeper than ten centimetres are left to uncover later on. Larger tools such as pickaxes can be used to break away harder soils, while shovels are needed to transfer any earth removed into a wheelbarrow for further inspection.

© Alamy

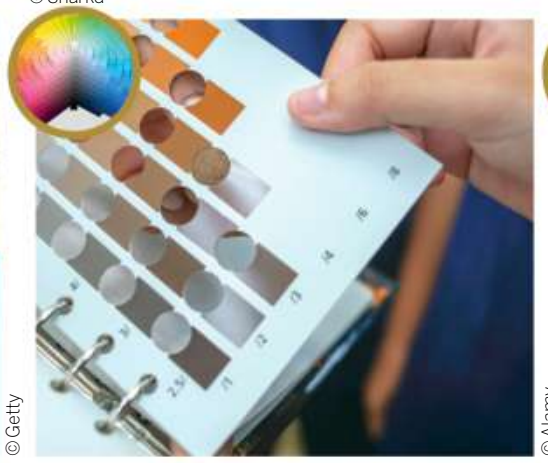
4 Recover any finds

Some artefacts, such as ancient skeletons, can be extremely delicate. To uncover these remains safely, small tools such as brushes and dental picks can be used to remove thin layers of dirt without damaging the find. Cleaning the surface allows photographs to be taken to document the positions of the bones before removing them from the ground.

© Getty

5 Bag the artefacts

The recovered artefacts are placed into clear bags that are labelled with a unique code. This number allows those analysing it later on to know where it was located. Finds are often arranged by material so that they can be stored appropriately.


© Sharkd

6 Check the soil levels

The colour of the soil that the artefacts are found in can tell researchers a lot about the composition and history. Accurate recordings indicate possible burning of material, farming activities and organic matter. Munsell colour charts are often used to compare against a soil sample. Each specific colour is given a unique name based on its hue, shade and strength.

© Getty

7 Sift for smaller items

Skeletons, whole fossils and other large artefacts will be spotted as the layers of soil are removed from the ground. However, some tiny finds could be hidden within the soil. All layers analysed are poured through a large sieve called a sifting screen. This can reveal tiny molluscs, seeds and pollen.

© Alamy

8 Record all progress

Keeping notes is essential, as once the artefacts have been moved from the site, analysis will rely on photographs and the details taken during the excavation. Field notes explain everything that was observed and any events that took place in each square of the grid during the dig. They also contain the writer's thoughts about the history of the site.

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OFFER EXPIRES 30 Apr 2021

HOW SMART GLASSES CHANGE REALITY

© Microsoft

The latest mixed and augmented reality tech will change the way we view the world

Words by **Ailsa Harvey**

When Google released 'Google Glass' in 2013, it was a novelty. The era of smart glasses was yet to really begin, and the idea of wearing this technology was largely scoffed at. Wearable technology varies from watches that count the steps you take in a day to heart-rate monitors for medical monitoring and intelligent fabrics that adapt to their surroundings. However, there's something about incorporating the key human sense of sight with this evolved technology that crosses the line between human and machine.

Smart glasses overlay information and graphics onto the real world. The result can be both a surreal blend and a beneficial tool. Google Glass demonstrated what the future could be. Like carrying around a personal assistant in your eyes, the glasses could quickly answer questions about the world around you, take photos, send messages or offer directions and useful information as you navigate a city – and all much faster than if you reached into your pocket for a smartphone. However, Google's smart glasses weren't successful in creating a new technological revolution at the time.

Rather than giving rise to a population of smart glass wearers, not everyone was ready for them, while others branded it as an invasion of privacy. The fall of Google Glass was far from the fall of smart glasses, though, and today many companies have designed their own. Google Glass may have arrived before its time, but it taught today's technological pioneers what was possible. The latest smart glasses have been tailored to specialised purposes, making them far more desirable to certain industries.

Social media immersion

For those who want to look at the world through rose-tinted glasses, or edit their surroundings to suit their mood, Snap Spectacles 3 could be the answer. From the makers of Snapchat, this social media platform has been transformed within AR glasses, enabling the wearer to create the illusion that they live inside a Snapchat filter. Two cameras at the top of the lenses add greater depth perception, meaning that the computer-generated additions are better incorporated.

Not only can wearers experience dreamlike visions while wearing them, they can capture and record moments in time to save or send to friends via the social media platform. This adds the ability to share your experiences and allow a third party to witness an event through your eyes.

© Getty

Snap Spectacles were first released in 2016

© TCL

These glasses are due to be released for purchase this year

Cinematic viewing

When it comes to watching films or other entertainment, many would say that the cinema is the optimal viewing experience. There's something about being presented with a giant screen that enhances the experience. The reality is that most people can't go to a cinema every time they have a show to watch.

Now, however, it's been made possible to take that cinema feeling wherever you go. TCL's wearable display glasses create the illusion of being four metres away from a 140-inch screen, and can also provide three-dimensional viewing. Even when packed onto a busy bus, just wearing this device transports the mind to a spacious personal viewing area. Because of their slim and discrete design, onlookers would never guess that the wearer was experiencing their own personal cinema behind the lenses.

AUGMENTED ASSISTANCE

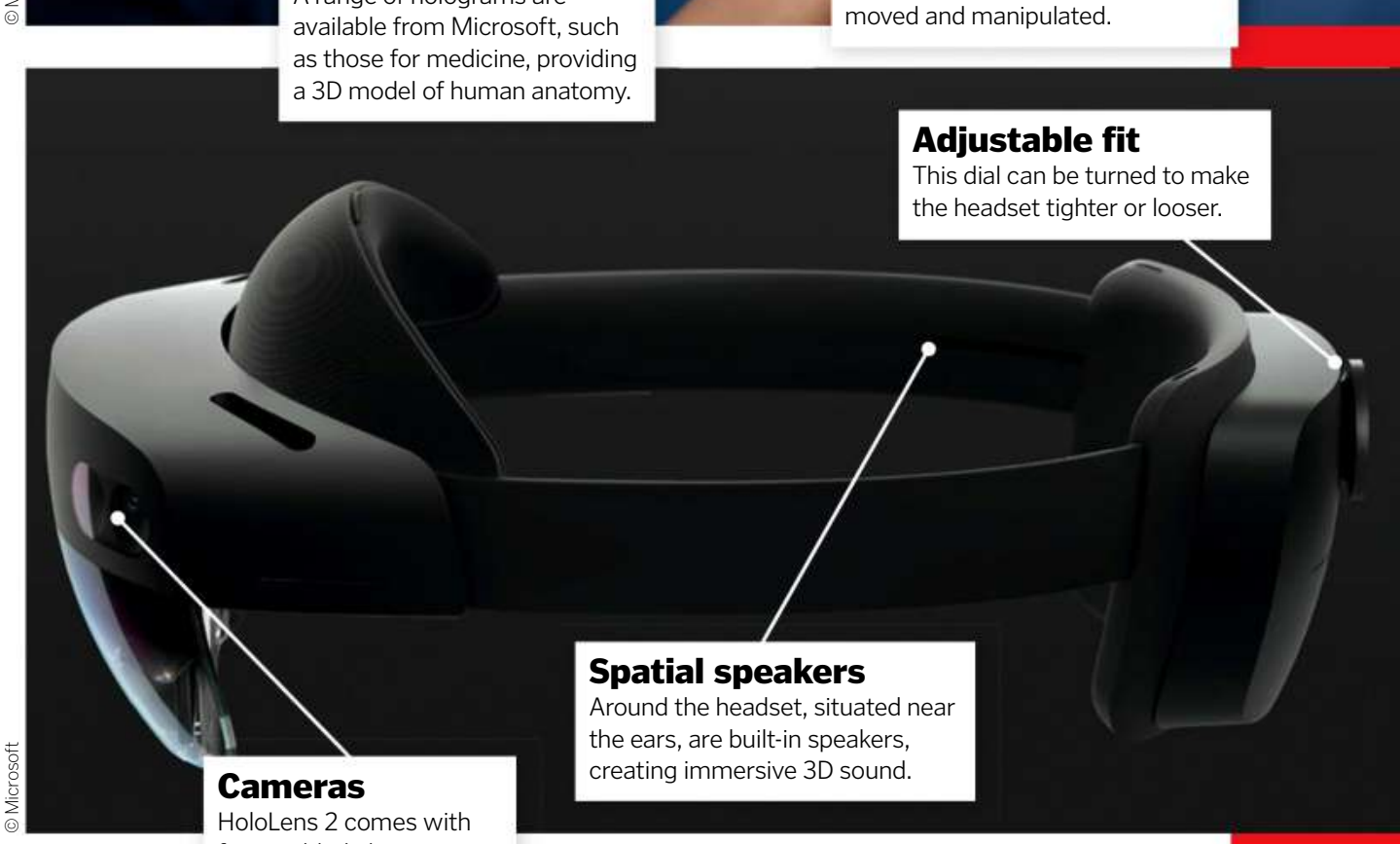
Train and learn using the interactive holograms of HoloLens 2

At first glance these glasses may look like something you would buy for a virtual-reality gaming experience. But the main purpose of this device is to drive productivity. These mixed-reality smart glasses by Microsoft can be used by a range of businesses and have various educational uses.

Merging textbook content with real-life experiences, HoloLens 2 allows you to study the inside of objects using holograms, practise practical jobs virtually and use informative videos to guide you through a real procedure. For employees being trained in practical roles, they can type labels onto objects to remember their names or functions, while designers can add objects or patterns that follow the three-dimensional curves of walls. This means they can view the overall effect of what they have imagined before committing to a design.

"The main purpose of this device is to drive productivity"

Microsoft's Remote Assist program allows calls to be made from the headset. If someone on the job needs input from a colleague, they can join the call and see what the wearer is seeing. Then they can add virtual documents to the headset's vision and click on the objects they think their colleague needs assistance with. Arrows will point the wearer in the right direction and allow them to do their work more efficiently.



© Microsoft

Eye recognition
When turning on the device the user can log in instantly, as the glasses recognise your eyes.

Informative text
Incorporating text into the viewing experience allows names to be remembered. As a training tool, labels can be created by the wearer for parts of real-life objects or holograms.

Double-lensed
There are two layers of lenses, with the inner section being used to project holograms. The outer lens is tinted.

Educational tools
A range of holograms are available from Microsoft, such as those for medicine, providing a 3D model of human anatomy.

Interactive holograms
Using movement and heat tracking, when the sides of the hologram are pinched, it can be moved and manipulated.

Adjustable fit
This dial can be turned to make the headset tighter or looser.

Spatial speakers
Around the headset, situated near the ears, are built-in speakers, creating immersive 3D sound.

Cameras
HoloLens 2 comes with four visible-light cameras and two infrared trackers.

FRONTLINE TOOLS

ThirdEye's X2 mixed reality glasses helps first responders to react quickly

© ThirdEye

To change the settings and viewing options, the wearer taps the air where they view the virtual button

An infrared camera can be attached to the glasses to analyse a person's body temperature

© ThirdEye

Six degrees of freedom

Many virtual reality headsets use three degrees of freedom to detect your head's tilt and direction. ThirdEye X2 also tracks your body's movement across three axes, to cover both position and orientation.

Headphone jack

There is the option for the wearer to connect their headphones for private listening or use the built-in speakers found next to the headphone jack.

Inside the X2

How ThirdEye's glasses function

Battery

The 1,900 mAh lithium-ion battery can be placed on fast-charge mode.

Selection buttons

Three buttons allow you to control the settings on the device. The buttons allow you to select items like a hologram, take you to the home menu and power the device.

Watch how surgeons use live data streamed to smart glasses to teach new techniques

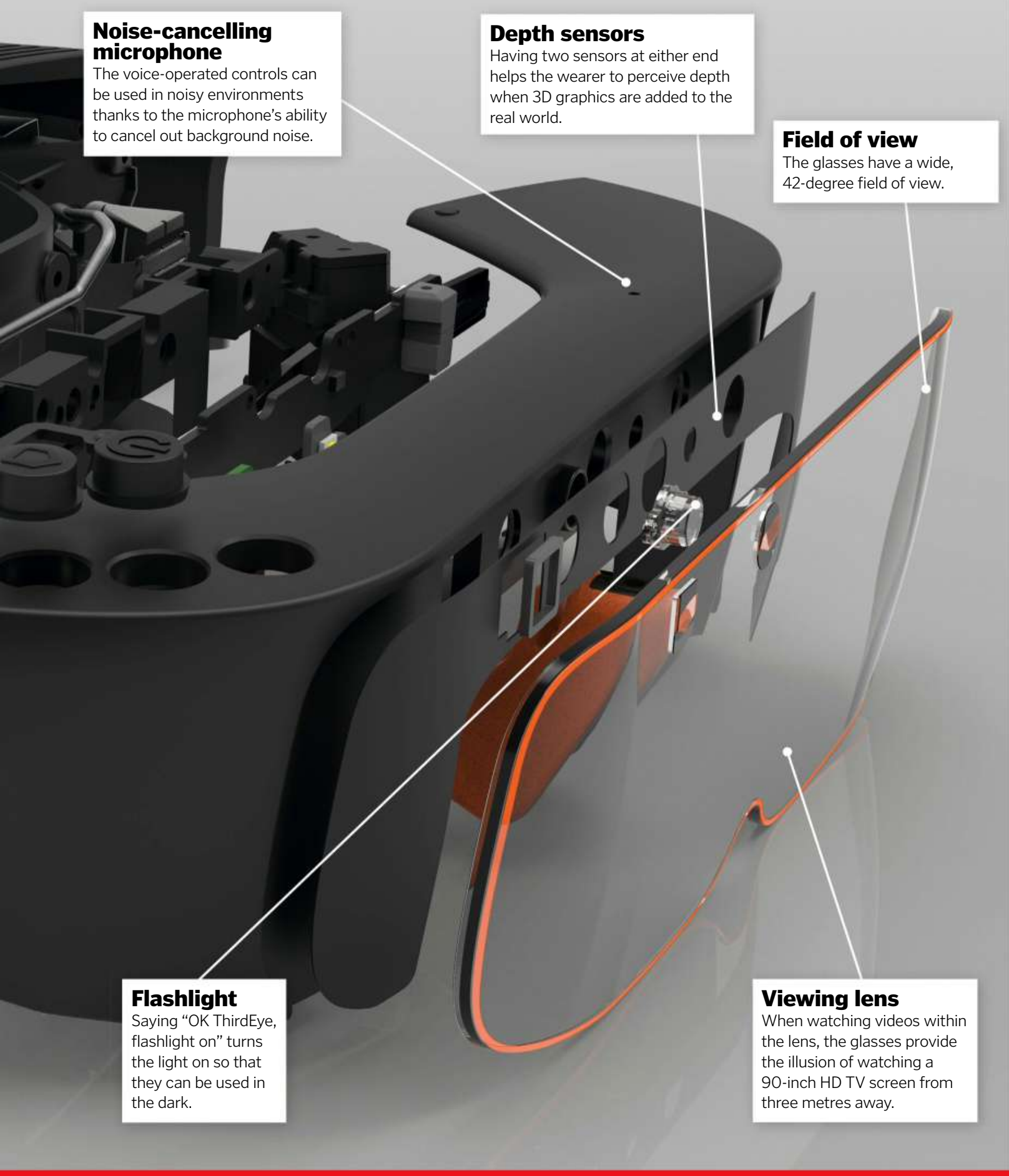
AR ZONE! SCAN HERE

© Getty

For first responders, such as medical staff arriving at an emergency, quick thinking and applied knowledge become life-saving tools. But why rely solely on the human brain? Holding the answers to the crucial next steps at times like these, medical staff can use the mixed-reality glasses to further their confidence that they have done the best they can.

Showing multiple screens at one time without obstructing the first responder's view of the patient in front of them, data can be read while carrying out their job. The cameras can also be used for facial recognition, bringing up the patient's medical records. This can be vital in allowing the paramedic to provide the best care for the patient's specific needs.

As well as detecting faces, the cameras can stream live footage of what the wearer can see, including the patient's changes in health. This allows staff at the hospital to prepare more effectively for the next step, and reduces the time taken for observation at the hospital. With thermal sensors, the X2 smart glasses have proven particularly useful during COVID-19. At a time when contact needs to be limited to protect first responders and patients, this technology allows the temperature of those with the virus to be taken without any contact.



Noise-cancelling microphone
The voice-operated controls can be used in noisy environments thanks to the microphone's ability to cancel out background noise.

Depth sensors
Having two sensors at either end helps the wearer to perceive depth when 3D graphics are added to the real world.

Field of view
The glasses have a wide, 42-degree field of view.

Flashlight
Saying "OK ThirdEye, flashlight on" turns the light on so that they can be used in the dark.

Viewing lens
When watching videos within the lens, the glasses provide the illusion of watching a 90-inch HD TV screen from three metres away.

An aerial experience

Aerial footage can expand upon the capabilities of handheld cameras. Drones have become incredibly popular as a method of exploring and shooting footage from a unique angle. If you've ever flown one before, you might wish you could take the journey too. Epson's Moverio BT-300 glasses give the wearer the feeling that they are inside the drone. As you fly the drone, your vision soars to give you a bird's-eye perspective of the world around you.

This smart technology can also detect points of interest, providing information about what you are looking at. On landing the glasses will flag up any issues with your chosen landing zone, such as uneven ground, and magnetic interference from surroundings such as TV masts. This allows you to bring the drone safely back to the ground without any complications.

© Alamy

The Epson Moverio BT-300 connects to a trackpad to control a drone

Sport assistant

For any sports enthusiast who loves to study the data collected about their workout, Solos' smart glasses incorporate your timing, power, heart rate and other data into your vision. Whether cycling along a main road or practising your running sprints, you no longer have to divert your attention and glance at a watch.

As well as recording your performance, these glasses come with other useful tools for when you're on the move. Directions can appear as holograms through the lens, pointing you in the right direction of your destination, while if you need to place a call during a bike ride, the voice-control features mean your hands remain free for the handlebars.

© Getty

Solos Smart Glasses are used by Team USA cyclists to monitor their training

High-tech classrooms of the future

Could these technologies soon become the norm in your school?

3D printers

Why bring in something for show and tell when you can print it in class? From geometry to anatomy, 3D printing offers a unique opportunity to print out customised educational tools and models to explore a wide range of school subjects. 3D printing has already revolutionised manufacturing around the world – around 80 per cent of high-tech manufacturing relies on 3D printing for prototyping in the US. Lessons in 3D printing may soon have to become the norm, especially in lessons in engineering and computer-aided design (CAD). Currently, 3D printers aren't strange to see in classrooms around the world, though they're yet to be commonplace. In 2019, CREATE Education Project and Rolls-Royce teamed up to create the first Primary Education 3D Printing Hub to support schools around the UK with access to 3D printing.

VR field trips

Could future field trips be held in the virtual world? Virtual and augmented reality have already proven themselves to be exciting new educational tools, allowing students to access new visual learning tools. This could soon extend to taking students on immersive field trips without the need to travel. Companies such as Nearpod and ClassVR are making it so VR can transport students to international sites. From the Pyramids of Giza to the outer reaches of our Solar System, students could be instantly transported to the many wonders of this world and beyond. The rollout of 5G connectivity could also play a large part in the success of VR in classrooms. Thanks to its ability to ferry large amounts of data, 5G would allow high-definition remote VR headsets to function without being tethered to desktop computers.

AI teaching assistant

Artificial intelligence continues to infiltrate many different areas of industry, but could that include your classroom? Although we are many years away from having a cyborg teacher at the head of the class, AI's current role is more on the administrative side, distributing homework, offering feedback on work and supporting a human teacher-led class. China's education system has been the first to truly embrace the technology of AI-assisted tutoring. Companies such as Squirrel AI Learning are delivering both AI online lessons from home and in high-tech tutoring centres for advanced one-on-one tutelage. In its first five years, Squirrel AI has opened 2,000 learning centres and registered over a million students.

© Getty

A Squirrel AI Learning platform at the 2019 World Artificial Intelligence Conference

Interactive teaching

In a world where we get our information from multiple sources, classrooms may adapt to include interactive technologies such as multi-touch screens. Studies at Harvard University have found that the traditional 'chalk and talk' method of teaching is less effective than active learning. This includes collaborative work on interactive devices, such as touchscreens, and augmented reality. In the future, the single-contact touchscreens of smartboards may be replaced by large-scale multi-touch and multi-user LCD screens. This advanced technology would allow multiple students to research, present and display educational tools and information at the same time. It would essentially be a wall-sized iPad that several students could use at once. At the moment, multi-user screens of this kind are predominantly being offered for corporate use by tech giants such as Panasonic, albeit on a smaller scale. In the future, these highly interactive screens may make their way into the classroom.

Robotic classmate

If we've learnt anything over the last year, it's the importance of education and helping those that can't physically come together to learn. However, this isn't a new hurdle for children with long-term illnesses unable to attend class. In 2018, the Hospital and Outreach Education project in the UK was granted £522,142 (around $730,000) to provide continued education to children with a long-term illness until they're able to attend school. This money helped to further the development of anti-isolation robot AV1, created by Norwegian company No Isolation. This small classroom stand-in allows children at home to listen, watch and communicate during a lesson. The robot lets children engage in lessons and interact with their peers from the safety of their homes or hospital beds. AV1 is operated through an app so the child can control its movements, microphone and speaker. These telepresence robots are growing in popularity in many different industries. For example, they will appear at the next Olympics to provide people with remote attendance.

AV1 allows children to engage in lessons without the need to physically be at school

Cloud computing

Cloud computing has changed the way many of us work and operate online during this global pandemic, and will continue long after it's over. For schooling, the ability to have all your work saved and accessible from the cloud not only increases remote accessibility to lessons but means you can never use the classic 'the dog ate my homework' excuse again. Cloud computing not only improves the way work is stored online, but may grow the number of students in a class, potentially from around the world through distanced learning. This upgrade to the way students learn and work may eventually lead to tablets replacing the humble pen and paper in classrooms. This would also support the growing trend in game-based learning, which is projected to jump in value from $3.5 billion (£2.5 billion) in 2018 to around $24 billion (£18 billion) by 2024.

AR ZONE! SCAN HERE

© Illustration by Nicholas Forte © No Iso at on

Xbox Series X teardown

Discover the technology behind Microsoft's latest console

Meet the fourth-generation Xbox console, which launched on 10 November 2020 at the same time as the less powerful Xbox Series S. It represents the latest in Xbox gaming technology, bringing enhanced graphics and more realistic lighting effects, as well as better response times thanks to an increased frame rate of up to 120 frames per second.

Physical discs are no longer a requirement to play, with games available as digital downloads from the Microsoft Store. To make the transition smoother between your old Xbox and the Series X, you can still play many of your old games from previous generations on the new console. The Series X is compatible with thousands of titles that were originally released for Xbox One and Xbox 360. A subscription to Xbox Game Pass can be purchased too, granting access to hundreds of games. This feature has proven both desirable and cost-effective for those who spend many hours gaming.

For most, the improved graphics and fast-paced action of the Xbox Series X are the main reasons to purchase the upgraded console. Who doesn't want to be gaming using the most advanced technology? However, its designers have put in an equal effort maximising the console's efficiency and practicality under the hood. Take a look inside the console to discover how it has been engineered to create a cooler and quieter gaming experience.

The new console is nearly twice as big as the Xbox One X

Inside the box

How Microsoft has upgraded Xbox hardware to create the ultimate gaming console

Optical drive
This DVD and Blu-ray disc reader is the same as the one found in the Xbox One.

Copper vapour chamber
This metal device distributes heat generated by the system throughout the chamber. As heat enters the component, it turns deionised water contained inside into vapour, dissipating heat up through the device to be removed by the fan.

Electromagnetic (EM) shield
This metal shield protects the motherboards from electromagnetic interference by absorbing EM signals from the air, without trapping heat. Unlike previous models, the EM shield is localised to cover the motherboards rather than encasing the entire device.

Power supply
Producing a total of 315 watts, it trumps the Xbox One X power supply by 70 watts – necessary for the more power-hungry components.

The smaller Xbox Series S is an entirely digital version of the Series X

Scene sharing

An extra button has been added to the latest Xbox controller, allowing players to instantly capture and share footage of their game. The share button can be found at the centre of the controller. When pressed and released the button takes a screenshot, while holding it down records the gameplay. This ease of access means that when the action gets particularly exciting, recordings can be made spontaneously without having to pause or interrupt play.

For those irritating times when your most impressive gaming moments occur and no one is watching, this feature allows you to store your best bits and share them with friends. Unlike other recording devices that require you to be ready to guess when the best footage will take place, this feature lets you record afterwards, capturing the action that has just happened.

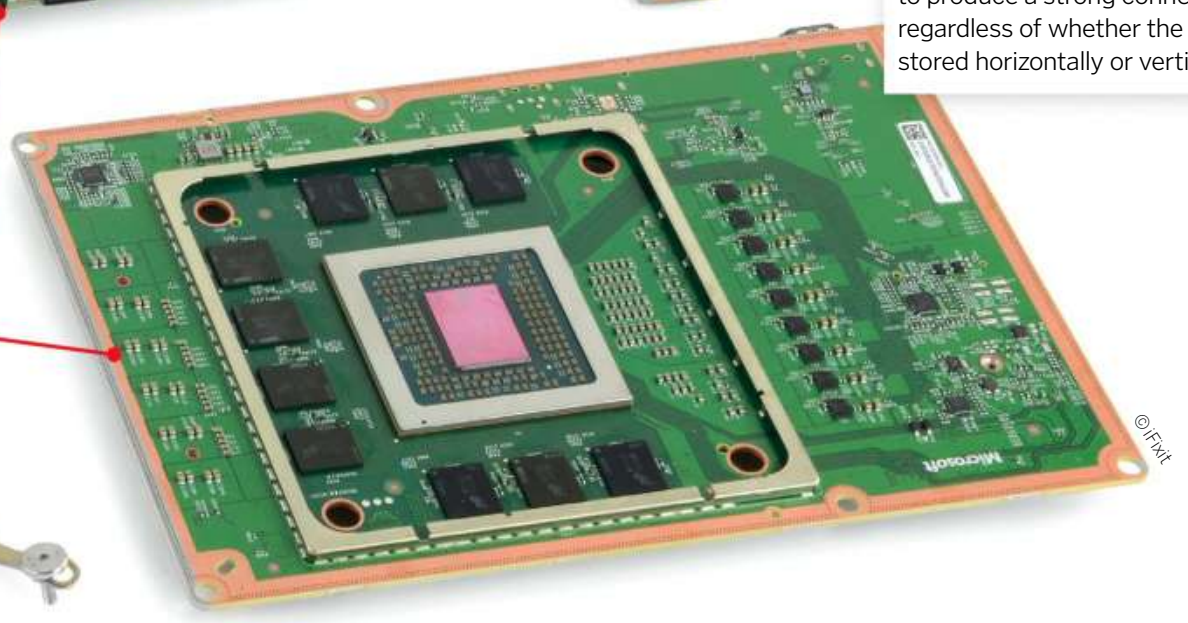
The share button can be found directly below the Xbox button

Fan
A 130-millimetre fan blows hot exhaust out the top of the console when standing upright.

Antenna board
Two of these boards detect and focus the WiFi connection. Attached to two sides of the device, it means one will be able to produce a strong connection regardless of whether the Xbox is stored horizontally or vertically.

Heat sink
Taking up the majority of the space inside, the heat sink is designed to draw heat out of the console's components quietly.

Double motherboard
Rather than the usual single motherboard, this system is divided into two to distribute heat more effectively.



"Designers have put in an equal effort maximising the console's efficiency and practicality under the hood"

Speedy Ripsaw snow tank

How the world's fastest dual-tracked vehicle works

Off-road driving can be invigorating in most circumstances. But as you cover increasingly unreliable ground, how much trust can you put in your vehicle to safely continue its journey? The bumpy and disorderly drive you would expect to experience when travelling over rocky obstacles and deep snow disappears when inside the Ripsaw tank.

Designed by Howe & Howe Technologies, the Ripsaw EV3-F4 is described as the 'Floating Cockpit', and claims to be able to cover any terrain. As its occupants sit high atop the tracked wheels, travelling at up to 60 miles per hour across rough ground, you can see why this beast is described as such. With an array of windows to keep the driver and passengers fully immersed in their surroundings, the tank glides with ease over even the most treacherous terrain types.

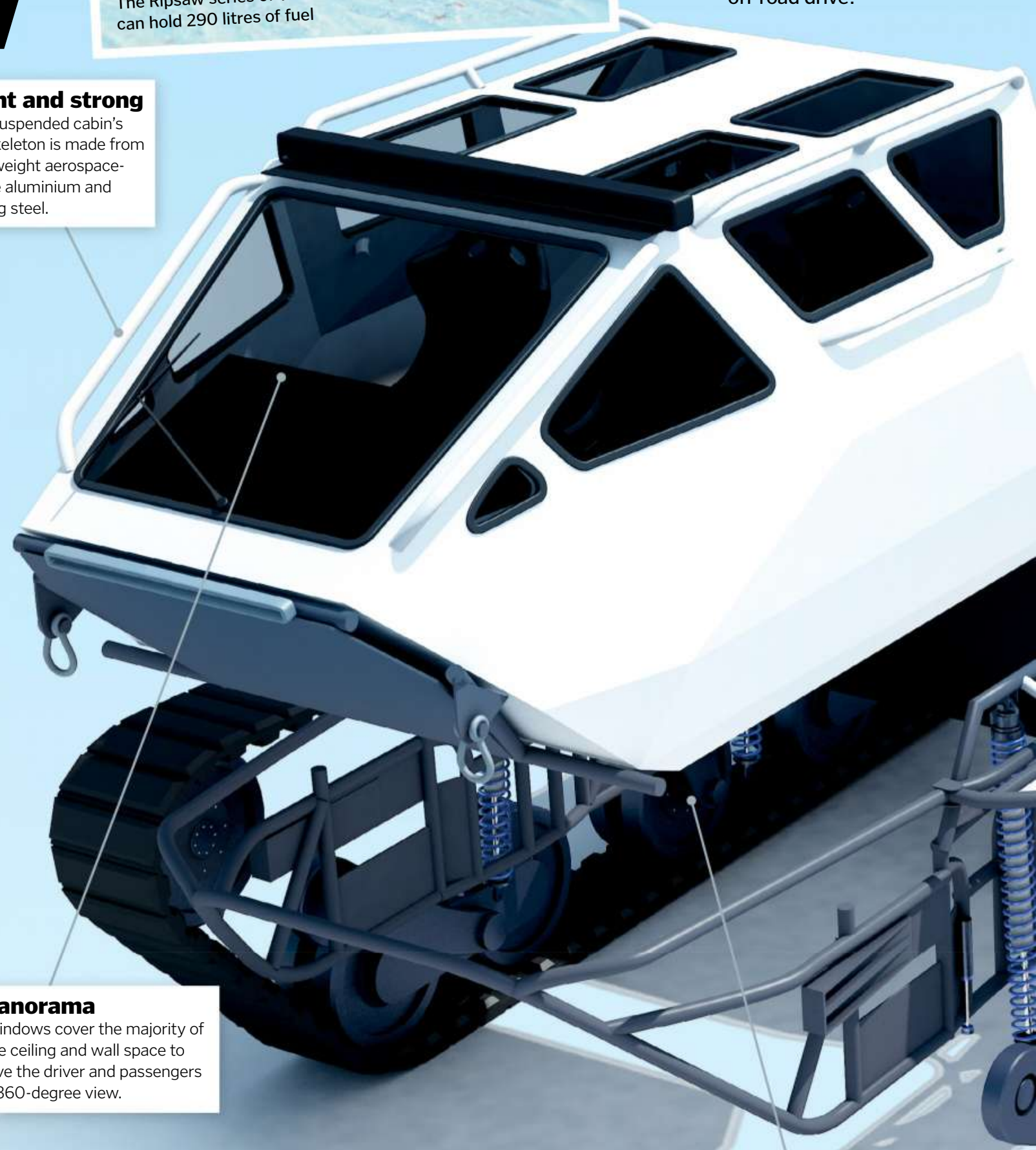
Ripsaw vehicles caught the eye of the military, and the US Army used them to traverse various war zones during defence, surveillance and explosive disposal missions. However, today these mighty specimens are also available for civilians to purchase.

Due to the increasing number of variations being produced through customisation, the price tag can vary. But all you need to boast about having your own all-terrain tank is around £500,000 ($675,000) and some epic, off-road terrain to show off on.

The Ripsaw series of vehicles can hold 290 litres of fuel

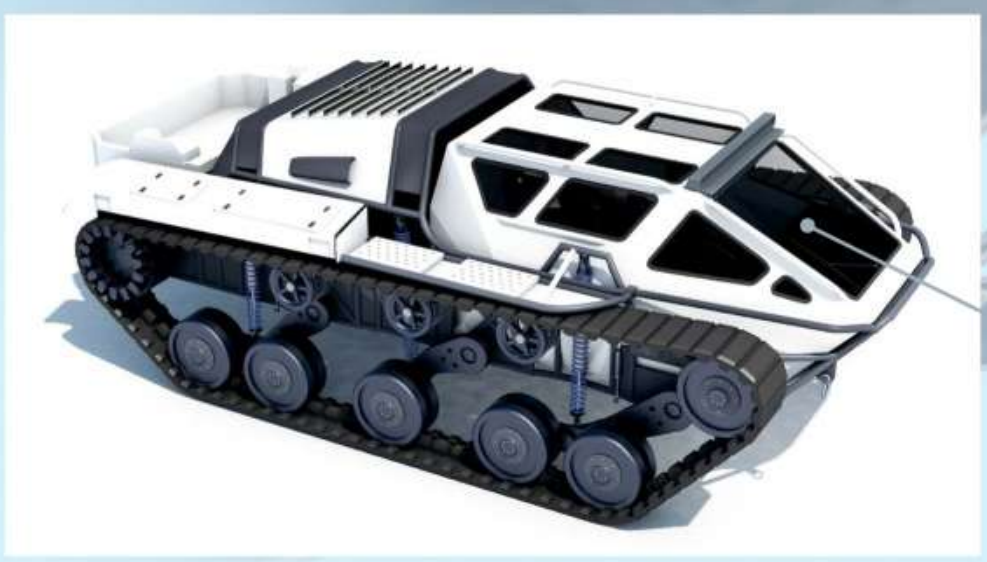
Riding the Ripsaw F4

What technology produces this smooth off-road drive?



Light and strong
The suspended cabin's exoskeleton is made from lightweight aerospace-grade aluminium and strong steel.

Panorama
Windows cover the majority of the ceiling and wall space to give the driver and passengers a 360-degree view.



4,500 kilograms
Despite its bulk, this tank maintains speed and manoeuvrability, with a minimum turning radius of just 2.4 metres. A passenger car has a turning radius of around ten metres.

Passenger potential
While earlier models had limited passenger space, this commercial variant allows three people to ride alongside the driver.

Luxury controls
The heated steering wheel comes with paddle shifters for quick gear changes.

Digital dashboard
This dual display presents data such as live images from the 360-degree cameras.

Power to weight
The vehicle produces a power of over three kilowatts per kilogram.

Clearance
There's 50 centimetres between the ground and the passenger pod.

Constant contact
284 centimetres of rubber track covers the ground at all times to increase traction on the slippiest surfaces.

AR ZONE! SCAN HERE

The tank's tale

The first variant of the vehicle was created 20 years ago by Michael and Geoff Howe, founders of Howe & Howe Technologies. The twin brothers aimed to create the fastest tracked vehicle ever designed, and targeted their product for army use. After the military adopted it, largely utilising its remote-controlled capabilities for unmanned missions, the Ripsaw soon gained public interest.

Though the brothers originally declined offers from civilians, they later realised the possibilities. Being based in the US, the majority of interest in the vehicle comes from ranch owners with a bit of space to play with. After all, there's a reason that this vehicle is classified as 'off-road', with its unstoppable nature making it illegal on public roads.

Owners often customise their tank with stand-out colours and interior changes

All images © Howe & Howe, Inc.

A real-life transformer

For this metal beast of land and sky, no destination is inaccessible

The Black Knight Transformer can move across the ground with the speed and suspension of a typical off-road vehicle. Then it can ascend vertically into the sky, flying forward through the air. Black Knight gains its 'Transformer' title for its ability to do both effectively, altering its shape for a smooth transition between the two vehicle types.

But what's the purpose behind designing this multi-functional machine? Beginning development in 2010, aerospace company Advanced Tactics aimed to create a troop carrier for military use that would increase safety for its passengers. The main missions engineers had in mind were deliveries of supplies and the extraction of injured or stranded soldiers.

When attempting to reach specific destinations on a battlefield, a decision needs to be made to determine whether access by ground or air is safer. Sometimes neither vehicle choice is perfectly suitable. If soldiers are in need of assistance in the heat of battle, landing a helicopter becomes almost impossible under enemy fire. Meanwhile, choosing a truck that travels solely on the ground can be limited by high obstacles and treacherous terrain. But what if you have a vehicle that can drive and fly? This is one of the main benefits of the Black Knight. It can first take to the sky, scouting out a safe and appropriate landing spot nearby before converting into a truck for a more discreet approach to the troops. Advanced Tactics is currently working to improve this concept, with the aim of eventually rolling out these transforming vehicles to the US military.

Entrance
A door pulls down from the back of the vehicle to allow troops and equipment to be loaded and unloaded.

No tail rotor
The propellers spin in opposite directions on the two sides, which counteracts the directional forces. This prevents the vehicle from spinning and means that no tail rotor is needed.

Truck tyres
The vehicle has been given four large truck tyres for increased balance and traction, as well as shock absorbers to handle uneven terrain.

AR ZONE! SCAN HERE

Driverless missions

During military missions, the Black Knight could be released onto a battlefield without a driver. In the event that troops need to be returned to base camp, or emergency supplies are required, the soldiers notify their nearest base. The Black Knight is then dispatched to the requested coordinates, and can be controlled remotely from the base. If the troops that requested the vehicle are not near a safe landing zone, they can choose the best place to meet it by assessing their surroundings. When it lands, any uninjured troops can take control of the Black Knight and navigate to where the wounded lie. With the choice of manual navigation and remote flight to return to safety, injured soldiers can reach treatment more quickly without putting a flight crew at risk.

Engineer Rustom Jehangir, who's 1.8 metres tall, stands next to the vehicle

© Advanced Tactics

The Knight's design

How does this multi-skilled vehicle function?

Substantial size
At nearly six metres long and 1.2 metres wide, the main body of the vehicle has a large interior to hold troops or deliveries.

Extendable arms
The arms fold inwards to face the centre of the vehicle when on the ground, keeping the vehicle compact.

Propellers
The eight propellers are linked to a computerised feedback system which keeps the thrust between opposite rotors equal. This maintains balance of the two sides during flight.

Multiple engines
Eight four-cylinder gasoline engines are attached to rotors, with each powering one of the double-bladed propellers.

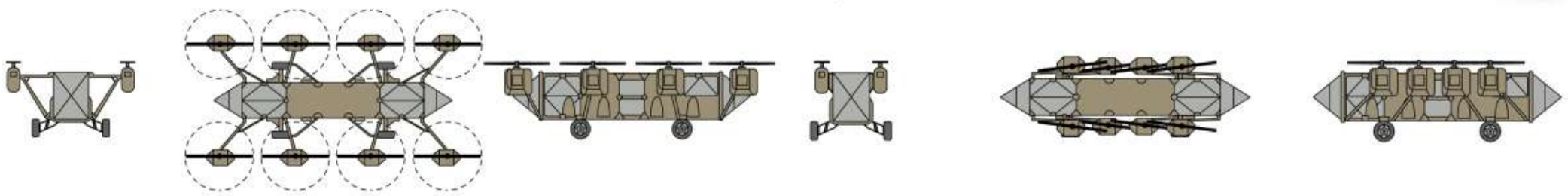
Driver view
When operated by a driver, the glass design allows for a panoramic view of the surroundings, including above and below.

It's a helicopter and truck all in one

© Advanced Tactics

Double threat

What makes this vehicle part helicopter and part truck?



Helicopter mode
When the propeller arms extend outwards, the vehicle's width more than doubles in size. As its eight propellers rotate, gaining speed, the vehicle lifts vertically from the ground. The Black Knight is able to spend up to 19 hours at a time in the air before returning to ground level. Along both sides of the vehicle's hull, four fixed-pitch propellers combine with engines to create both vertical lift and forward propulsion.

3,050 metres
The Black Knight can fly to one-third of Mount Everest's altitude.

100 miles per hour
Its horizontal speed is faster than that of many birds of prey.

1,995 kilograms
Its maximum takeoff weight is as heavy as four adult polar bears.

Ground vehicle mode
When travelling on wheels, the Black Knight's propellers move to the sides of the vehicle. This gives the vehicle a more stable centre of gravity and enables it to meet the legal dimensions for driving on most roads. In addition to being tailored to the small spaces of narrow city roads, the suspension and tyres keep the vehicle moving efficiently through some of the most challenging and bumpy terrain.

70 miles per hour
An independent engine powers the vehicle across the ground.

7.6 metres
The length is reduced by two metres when the propellers are retracted.

2.5 metres
The vehicle stands nearly as tall as an average single-decker bus.

© Illustration by Adrian Mann

WIN!
TWO SMARTWATCHES

This month we are giving you the chance to win a pair of Amazfit GTS 2e smartwatches. These all-round health and fitness trackers can monitor blood oxygen levels, heart rate and even stress levels while looking sleek and stylish.

For your chance to win, answer the following question:

What does the ‘A’ in DNA stand for?

a) **Antibodies** b) **Acid** c) **Aliens**

Enter online at **howitworksdaily.com** and one lucky winner will win!

Terms and Conditions: Competition closes at 00:00 BST on 8 April 2021. By taking part in this competition you agree to be bound by these terms and conditions and the Competition Rules: **www.futuretcs.com**. Entries must be received by 00:00 BST on 08/04/2021. Open to all UK residents aged 18 years or over. The winner will be drawn at random from all valid entries received and shall be notified by email or telephone. The prize is non-transferable and non-refundable. There is no cash alternative.

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AMAZING RAYS

Rays are fascinating – come and find out more about the lives of these shark-like creatures

Words by **Lauren Eyles**

DID YOU KNOW? *You can report egg case finds to the Shark Trust, who record where they are found for better protection*

If you've ever found a shark or skate egg case washed up on the beach after it's hatched out, you'll know how different they can be. You'll also know how they can be extremely deceiving, often being mistaken for seaweed or even plastic. These egg cases, sometimes called a 'mermaid's purse', can tell us a huge amount about varied species that can be found in oceans all around the world. But you won't come across egg cases from their cousin and relative, the ray. That's because they are viviparous, which means that they give birth to live young.

What distinguishes a ray from a shark? The biggest and most obvious difference is their body shape. You will notice that rays are very flat and very well adapted to life on the seafloor, where some spend a lot of their time. They bury themselves in the sand as the perfect camouflage to hide away from being eaten, and to grab a meal of worms, snails and shrimps. Rays have a disc-shaped body from having over-sized pectoral fins, which are actually part of their head. They also have thin, whip-like tails that might be used for movement, but protection is their main purpose – particularly for stingrays.

If you look at a ray from underneath, it looks a little like a cute, alien face smiling at you. But don't be fooled; it's not eyes you are seeing, but their nostrils, mouth and gills. The same features are found on the top of sharks' heads, alongside their eyes.

If rays are constantly sitting on top of what helps them to breathe, then how do they get oxygen? They solve this puzzle by having two small holes near their eyes called spiracles: when they are buried in the sand, they use these holes to breathe through. In fact, other types of animals on the planet have these too, like insects and other fish species.

There are many different species of ray in the world's oceans, including manta, devil, electric and stingrays – all different to the next, but all with an interesting story to tell. The manta ray has to be the celebrity of all the rays; they are the most recognisable and best known. They really are spectacular to see in the ocean. With so much grace and charm, they would stop you in your tracks if you were

© Getty

A stingray picking out food to eat on a sandy seafloor

© Getty

What's on the menu?

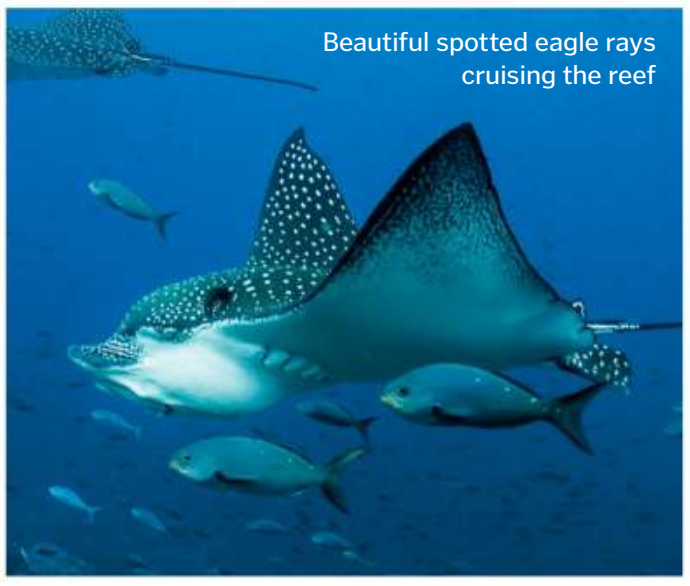
It's no wonder that most rays spend a lot of their time on the bottom of the ocean, as it's here that they can hunt down their food, which lives on, or within, the sand. With their squashed bodies, they can easily cruise along the seafloor with their mouth in perfect position to pick out crustaceans, worms, snails and sometimes fish and squid.

But manta rays and many of their close relatives are different. Like the biggest fish, the whale shark, and the biggest mammal, the blue whale, they feast on plankton – tiny little animals floating in the water. The strange-looking flaps in front of their heads that make mantas unmistakable are similar to fins, used to help funnel water and their favourite snack into their mouths. Giant oceanic mantas can come together in huge numbers to feed and have been seen working together to trap food.

exploring underwater. It's recently been discovered that there are two types, the reef manta and giant oceanic manta, and clues to their nature are in their names.

The reef manta is much smaller, spending most of its time cruising along tropical coastlines in areas of the Indian and Pacific Oceans. The giant oceanic manta wanders most of the world's tropical waters across great distances far out to sea, but sometimes comes closer to shore. The giant oceanic is the biggest ray in the world. With their wingspan reaching as wide as nine metres – the same size as two cars put together – they are true ocean giants. Rather than lounging around on the seabed like their ray relatives, mantas swim continuously, using their pointed fins to glide through the water, making them look like they are flying. Mantas and their close relatives, like the Munk's devil ray, take this one step further. They leap and fly clear of the water, with a giant belly flop to finish. There are a few theories as to why this breaching behaviour happens, but no one really knows for sure.

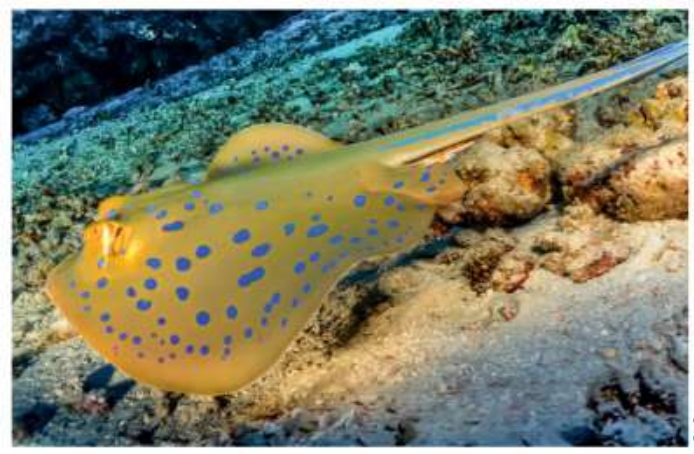
Electric rays, on the other hand, aren't quite as graceful travellers. But they are capable of doing something no other ray can, and that's producing and storing electricity just like a battery – enough to give a shock of up to 200 volts, which would knock a human out. They are sturdy-looking fish with small eyes that power through the ocean using their chunky tails in quick, jerky movements. There are a few different species – some with attractive patterns – in both warm and cooler seas worldwide.


Beautiful spotted eagle rays cruising the reef

© Getty

There are lots of types of stingrays. But one of the most stunning has to be the bluespotted ray. It's a ray that is mostly encountered by snorkelers and divers on coral reefs in tropical seas. They are like the kingfishers of the birding world, with striking-blue dots and lines that edge the length of the tail. The blues perfectly complement their green-yellow undertones, and they'll flash before your eyes as they try to hide away – they do not like being disturbed.

It's easy to be hypnotised by their beauty, but be aware of that tail. The vibrant colours are a sure survival sign, and show that they mean business. They have two poisonous spines on the back of their tails that can cause serious harm to any threats that get too close.


The dazzling, bright-blue spots of a bluespotted stingray help this animal survive

© Getty

And then there's the impressive spotted eagle ray, which is another type of stingray and a cousin of the manta. Unlike other rays, these fine-looking creatures have a prominent beak. They have a pattern of small, white dots covering their entire body that are unique to them, similar to whale sharks. They spend most of their time swimming out in the open ocean.

From the tropics to the cooler seas of the UK, things get a bit confusing. There are a few species like thornback rays, undulate rays, spotted rays and more, but they aren't actually rays at all. They are all skates, and we know this because they lay eggs. There are a few true rays that inhabit colder European waters, like the marbled electric ray and common stingray.

Sadly, the amount of rays in the world is declining. Many are slow to grow and mature and don't produce many young, leaving it quite a few years before having more. This means that overfishing of these incredible animals can significantly reduce their numbers globally.

Guitarfish

Guitarfish are strange-looking, but it's easy to see where they get their name from. They are in the same family as skates, sharks and rays. There are a few different species, but all look like a mix of both ray and shark. If you take a look at the front, they are flat and circular, just like a ray or skate. But towards the rear they are more shark-like, with a streamlined body, two dorsal fins and a powerful tail. For this reason, they are also known as the 'shark ray'. They are a mixture of everything, but grouped as a ray because their gills are underneath. Like many rays, they prefer life on the seabed.

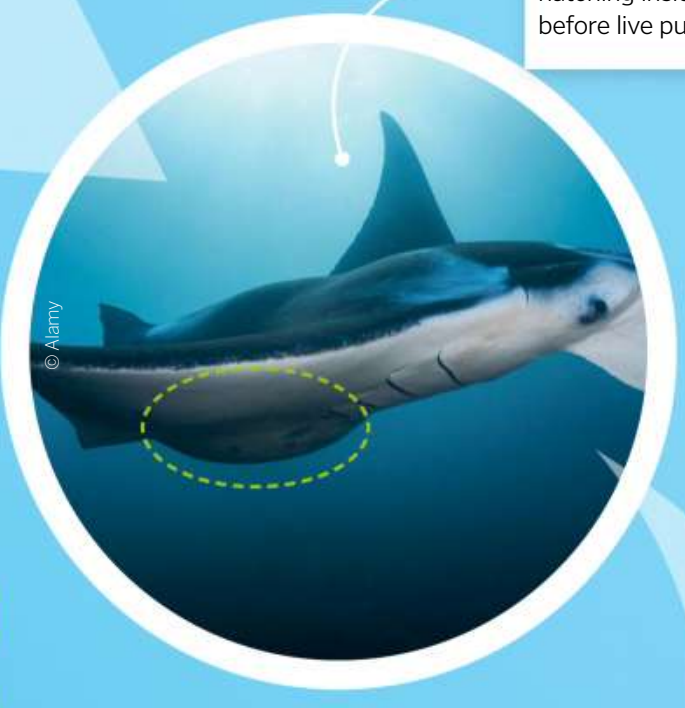
A single guitarfish in the shallow water – they like to be on their own

© Getty

LIFE CYCLE OF A MANTA RAY

Get to know the manta ray and find out a bit more about its lifestyle

1 Egg
Mantas develop as an egg inside the pregnant mother, hatching inside after a year before live pups are born.



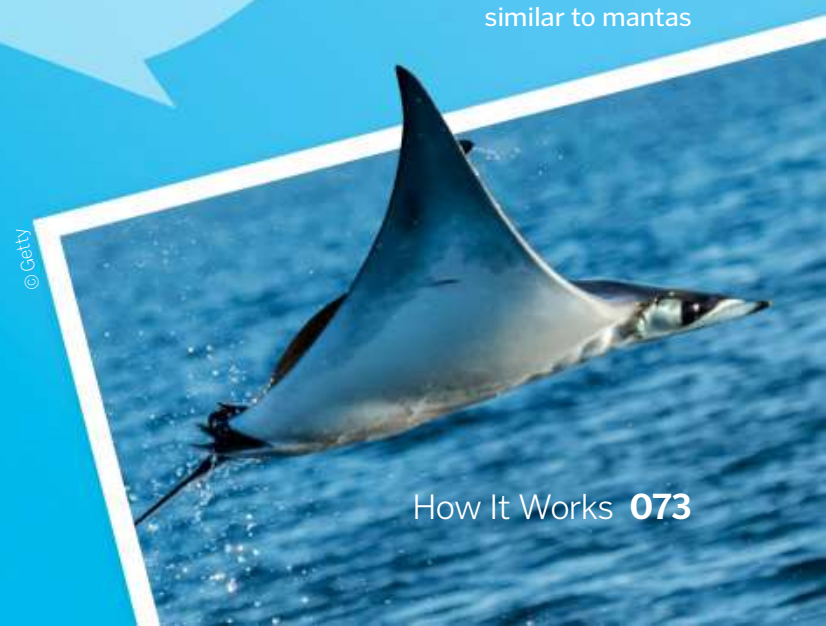
2 Yearling
Usually one pup emerges looking and behaving like the parents. Mantas generally give birth once every couple of years.

3 Juvenile
Left to care for themselves, little mantas begin to enjoy life finding food and moving around the ocean or reef.

4 Adult
They grow into mature adults and start to have pups of their own. Mantas can live for around 50 years.

5 Mating
Female mantas are ready for mating at around eight to ten years old. Pups are created inside the body, where an egg develops.

An acrobatic Munk's devil ray putting on a show – they look very similar to mantas



Cephalic lobes
These useful eating tools have given the manta ray the nickname 'devilfish', as they look like horns.

Cartilage
They are made up of flexible cartilage, like your nose and ears, rather than bones.

Open wide
They swim with their mouths wide open, hoovering up seawater and plankton.

Manta ray anatomy

A look at what makes a manta ray well adapted for their lifestyle

Gill plates
Food is filtered here to get all the juicy plankton out from the water.

Pectoral fins
Unlike other rays, mantas flap their fins through the water as they glide and swim along.

© The Art Agency / Sandra Doyle

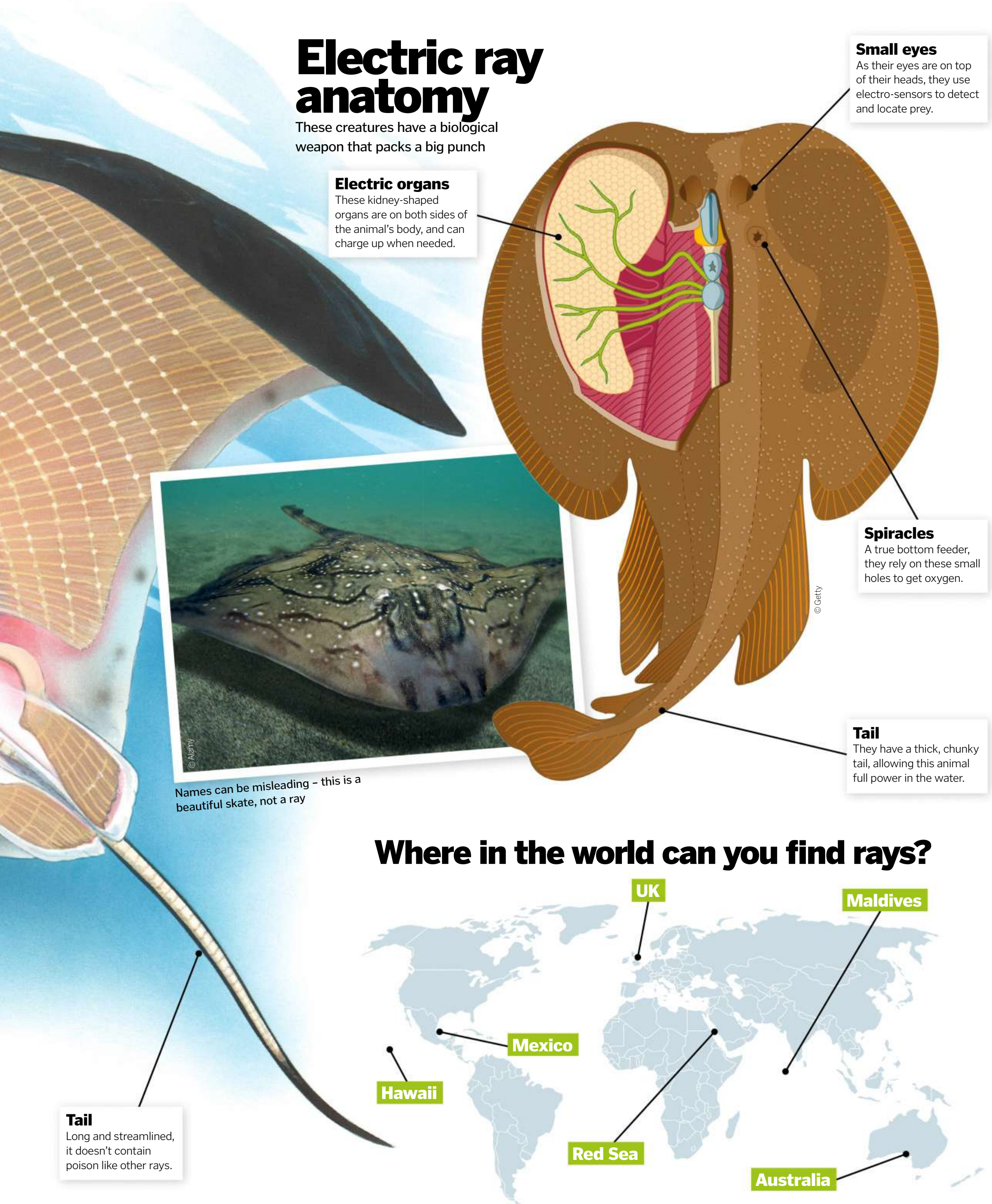
The belly of a marbled electric ray on the move

© Getty

"They really are spectacular to see in the ocean"

Electric ray anatomy

These creatures have a biological weapon that packs a big punch



Small eyes
As their eyes are on top of their heads, they use electro-sensors to detect and locate prey.

Electric organs
These kidney-shaped organs are on both sides of the animal's body, and can charge up when needed.

Spiracles
A true bottom feeder, they rely on these small holes to get oxygen.

© Getty

Tail
They have a thick, chunky tail, allowing this animal full power in the water.

© Alamy

Names can be misleading – this is a beautiful skate, not a ray

Tail
Long and streamlined, it doesn't contain poison like other rays.

Where in the world can you find rays?

INSIDE BEEHIVES AND WASP NESTS

Words by **Ailsa Harvey**

From building alone to serving royalty, these insects work tirelessly to create their perfect homes

It's usually around the summer months that you're most likely to encounter bees and wasps. As these frantic flyers approach, expertly dodging waving hands as they buzz about the flowers, it can be difficult to understand the lives of these busy insects.

But there's a good reason why you might forget about bees and wasps during the winter. Although many of them are still around, they are in hiding. Some have spent the entire year leading up to winter ensuring that their crowded nests are prepped for months in shelter. That sugary drink or picnic platter you introduced to their garden territory may have even played a small part in the growth of their nests.

The homes of bees and wasps are generally well hidden in rocks, trees and below the ground. The fact that you can't see them means that their predators are less likely to be able to as well. But if you were to access them, some would be teeming with activity, some would centre on a glorified ruler and others would house larvae left to fend for themselves.

With over 20,000 species of bee and 30,000 wasp species, each has developed a unique nesting system. A crowded social space isn't for every species, and not every bee or wasp in a colony gets to reap the rewards of their build. One thing that the majority of these insects do share is their dedication to work. Each role carried out by individuals in these habitats contributes to the insects' survival. With some species, the effort they put in to produce these architectural wonders provides benefits to us humans as well. Wasps act as pest control as they hunt prey to bring to their nests, while bees continue the cycle of life by pollinating plants as they prepare for hibernation. To learn more about how and why bees and wasps act in the ways they do, we need to look inside their homes.

© Getty

5 RECORD-BREAKING COLONIES

1 Biggest build
A 3.7 by 1.75 metre wasp nest found in Waimauku, New Zealand, in 1963 was the largest wasp nest ever found. The wood construction was so heavy that it fell from its tree, splitting in two.

2 Mega-queen
The biggest queen bee in the world belongs to the Wallace's giant bee species. The Indonesian queen bee is four times the size of a European honey bee, with a wingspan of over six centimetres.

3 Tiny flier
At less than two millimetres in size, *Perdita minima* is known as the world's smallest bee. It constructs miniature, solitary nests in the desert sands of the southwestern US.

4 Pub pests
The biggest wasp nest ever discovered in the UK was found in the attic of a pub in Southampton. The nest measured 1.8 by 1.5 metres and housed around 500,000 wasps.

5 Honey hoarder
Beekeeper Ormond Aebi reportedly broke the world record for the most honey obtained from a single beehive. In 1974 the beekeeper harvested 183 kilograms of the sugary substance.

This red mason bee is carrying mud to seal her nest

© Alamy

© Alamy

Solitary nesters

Some of these insects' breeding grounds lack a certain social buzz

Red mason bees

One of around 200 of the planet's solitary bees, the red mason bee has to search for a suitable egg-laying location that doesn't need to be built from scratch. This species only flies 90 metres from its nest, so an area that provides the female's needs is essential. First on the list is a suitable cavity, such as a hollow plant stem, dead log or a crack in a rock face. Here she can lay her eggs. This makeshift nesting place needs to be close to a food and mud source. The single bee will carry mud to the space where her eggs lie, and use it to seal them in. If the bee has to travel long distances to find mud, her unborn young are placed at risk of predation.

The smaller males are laid near the front of the nest, and are first to emerge. After growing up and finding a mate, females will repeat the hard work of their mother, building nests alone for the offspring they won't live to meet.

Grass-carrying wasps

The core component of a grass-carrying wasp's nest lies in the insect's name. These black, ant-like wasps pack hollow stems with nests of grass for their young to grow in. Cushioned and hidden between the blades, grass is used to create sectioned-off cells for each egg.

The first step for the female grass-carrier is to build the nest. Using her mandibles, she cuts the blades to the required size and carries this equipment to the nest. The building process also requires hunting. Stinging and immobilising her prey – usually tree crickets – the wasp embeds them in the blades of grass, ready for when her young need to eat. Wood can also be carried by these insects, placed between the eggs to create sections or at the end of the hollow to close it and protect the inhabitants.

Grass-carrying wasps' nests can be spotted, as they fill small holes with multiple blades

Inside a honey bee hive

Take a peek at this bee's hierarchy in action and discover how their sweet treat keeps them buzzing year-round

If you ever needed an explanation for the phrase 'busy as a bee', just take a look inside this honey bee hive. The majority of honey bees are experts at working, since chores are all they know. From the moment they are born in these advanced hives until their final day, workers create and sustain these wax hives.

When temperatures get too high, they distribute water around their home and fan it with their wings, while if temperatures drop they huddle together and warm it with their bodies. They feed the future queen, source food for the winter and build and fill storage cells.

Some honey bees create this hive of activity and survival in the bark of a tree. The perfect location will have a naturally occurring hollow and entry route so that the bees don't have to dig their space before creating the cells.

Honey cells
The worker bees share the nectar brought back from nearby flowers, chewing it in order to mix it with their saliva. This contains an enzyme which will change the pH and other chemical properties required to produce honey. Honey is dried and stored in designated cells for food during the winter months.

Melting wax
The bees' wax-making glands produce beeswax, arranged in circular tubes. As they work, the heat from their bodies causes the cells to melt into hexagons.

Smart design
The hexagonal cells of the honeycomb are the most efficient shape to maximise the number of cells built, with minimal wax used and producing no gaps.

Pollen cells
Some cells are used to store pollen. This protein-packed food source is fed to worker bee larvae. As a bee matures, it needs less protein and depends on the sugar and carbohydrates of honey and nectar.

The queen's guards
The queen bee has a group of guard bees, who form a circle around her. They keep this formation, with some walking backwards with the queen to ensure that their heads are always facing her.

Leaving the hive
A bee's work lies beyond the hive. Visiting between 50 and 100 flowers in one outing, the worker bees will come back with their 'honey stomachs' – separate from their main stomach – filled with nectar.

Nurse bee
Nurse bees secrete food for the larvae. Worker bees are fed 'worker jelly' by the nurse bees, which includes a combination of pollen and honey, while a protein and sugar-rich 'royal jelly' is provided for queen larvae.

Worker bee larvae
In its designated cell, it takes 21 days for a fully formed worker bee to develop from an egg. These female worker bees begin their hive chores as soon as they are born, clearing their cell for a new egg.

© Alamy

A honey bee queen is surrounded by a 'court' of bees who feed and groom her

Meet the queen bee

The queen is the largest, most powerful bee in the honey bee hive. Given superior treatment even before birth, the colony knows to cater for and respect the queen. When the queen nears the end of her life, worker bees build large cells for 10 to 20 potential replacements. However, there can only be one that dominates the hive.

The first act of the queen, after emerging from her cell, is to kill the other potential queens who were too slow to gain the title. If two emerge at once, they battle to the death. The surviving queen has two main roles. One is to mate with the drone bees, producing eggs to continue the colony, while the other is to produce 'the queen's signal'. Using 15 different glands, the queen produces pheromones. Similar to being put under a spell, these chemicals keep the colony working together and maintaining the hive.

Her pheromones can stop other females developing their ovaries, attract mates and bring the entire group together to follow her in swarms. Without these pheromones, the queen would lose her power to create a sense of order, a dedicated team and a hierarchy that benefits her, the colony and the continuation of the species.

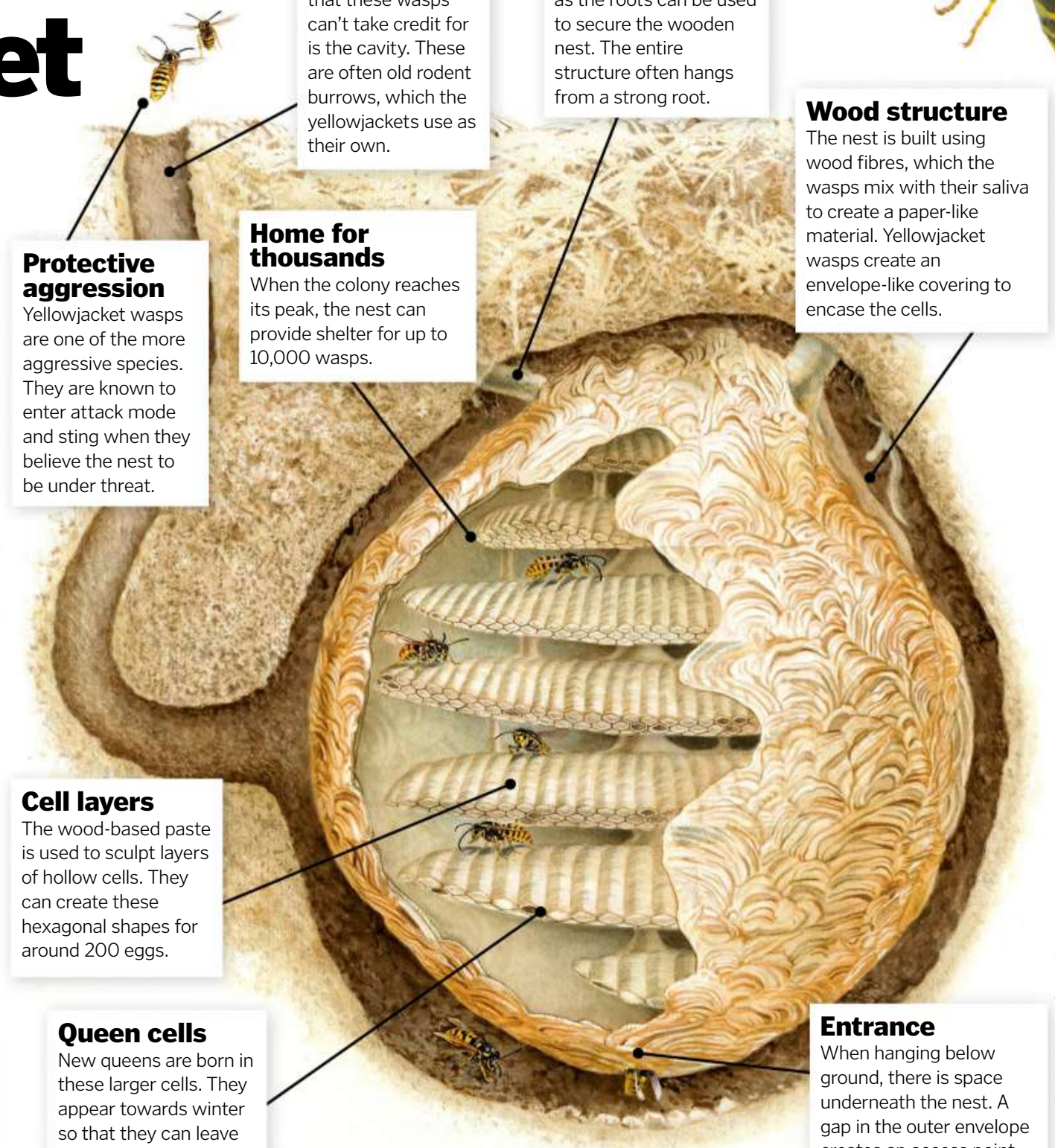
© Illustration by The Art Agency / Sandra Doyle

The nest of the yellowjacket

How does a single wasp raise a family of thousands?

A yellowjacket wasp nest grows rapidly in size over the course of a year, but drastically dies out during the winter months, with few survivors. Turning underground burrows, human-made structures and other cavities into wooden homes buzzing with life, the entrance to these wasps' nests is one place you don't want to mess with.

Yellowjacket wasps aren't afraid to sting. In fact, they are equipped to sting any trespasser who sets foot near the only entrance to their home and family. Born to defend these mighty structures, the nests of yellowjacket wasps and the thousands of buzzing bugs may lie right beneath your feet.



Repurposed burrow
One part of the nest that these wasps can't take credit for is the cavity. These are often old rodent burrows, which the yellowjackets use as their own.

Support root
Yellowjacket nests are often found under trees, as the roots can be used to secure the wooden nest. The entire structure often hangs from a strong root.

Wood structure
The nest is built using wood fibres, which the wasps mix with their saliva to create a paper-like material. Yellowjacket wasps create an envelope-like covering to encase the cells.

Protective aggression
Yellowjacket wasps are one of the more aggressive species. They are known to enter attack mode and sting when they believe the nest to be under threat.

Home for thousands
When the colony reaches its peak, the nest can provide shelter for up to 10,000 wasps.

Cell layers
The wood-based paste is used to sculpt layers of hollow cells. They can create these hexagonal shapes for around 200 eggs.

Queen cells
New queens are born in these larger cells. They appear towards winter so that they can leave the colony to mate.

Entrance
When hanging below ground, there is space underneath the nest. A gap in the outer envelope creates an access point for the wasps.

© Illustration by The Art Agency / Sandra Doyle

Wasp royalty

The yellowjacket queen puts in her fair share of hard work. As the only survivor over the winter months, it is her job to create a new nest. Having mated with male drone wasps, the queen finds a suitable location for her future colony. There she builds wooden cells to lay her eggs and goes foraging for food for them.

When the first of her offspring emerge, they become worker wasps and can help their queen to build the nest and grow the colony. Finally she can rest, knowing that others can continue her hard work. Her only role at this point is to lay her eggs in the cells, which are still being made. As the one fertile member of the group, the other wasps are very protective of their leader. They can become distressed and aggressive when they believe the queen to be in danger.

Source: Wiki/Opo Terser

The yellowjacket queen is around seven millimetres longer than a yellowjacket worker

Seasonal cycles

What bees and wasps are up to through the year

SPRING

BEE

When temperatures rise above nine degrees Celsius, honey bees emerge from their hives. Having used much of the stored honey, they search for flowers.

WASP

The queen yellowjacket emerges from hibernation and searches for a safe place to build her nest. The eggs she lays hatch into larvae.

SUMMER

BEE

The hive reaches its peak size, increasing the influx of food to the honeycomb. After the longest day of the year, the bees start to prepare for hibernation.

WASP

The colony's first generation of workers grow into adults as the season starts. For the remainder of summer, the queen will stay in her nest.

AUTUMN

BEE

As winter approaches, mating season ends and new queens are not produced. Any drone bees that are still in the hive may be kicked out for winter.

WASP

Male wasps and new queen wasps grow in the cells. When fully grown, they will leave the nest to mate.

WINTER

BEE

All the winter bees are born before the beginning of this season. They huddle together in order to keep the temperature in the hive warm enough.

WASP

The male wasps die when winter approaches, while the fertilised female wasps go into hibernation and prepare to start a colony of their own.

Oceanic dead zones

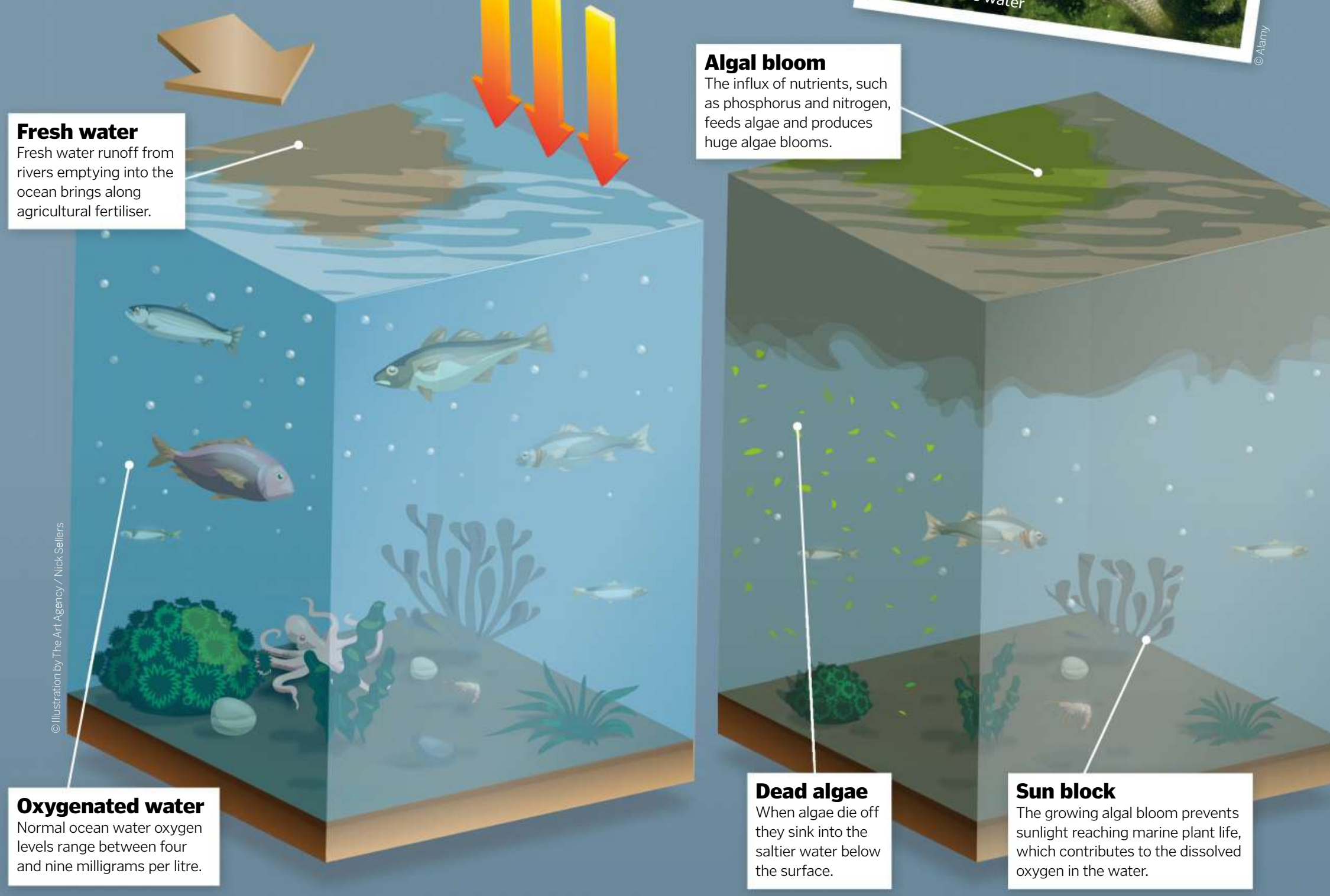
How too much of a good thing can lead to the death of an ecosystem

The Moderate Resolution Imaging Spectroradiometer (MODIS) snapped the Mississippi River emptying into the Gulf of Mexico, producing huge swells of algal blooms

© Alamy

Fish that have died from hypoxia float to the surface of the water

© Alamy


Fresh water
Fresh water runoff from rivers emptying into the ocean brings along agricultural fertiliser.
Algal bloom
The influx of nutrients, such as phosphorus and nitrogen, feeds algae and produces huge algae blooms.
Oxygenated water
Normal ocean water oxygen levels range between four and nine milligrams per litre.
Dead algae
When algae die off they sink into the saltier water below the surface.
Sun block
The growing algal bloom prevents sunlight reaching marine plant life, which contributes to the dissolved oxygen in the water.

© Illustration by The Art Agency / Nick Sellers

Along coastlines around the world are stretches of water where marine life is suffocating below the surface. As the name suggests, these 'dead zones' are areas where few species are able to survive or thrive. However, they are far from being completely dead. Rather than being filled with a myriad of different oceanic species, these areas are teeming with one type of organism: algae.

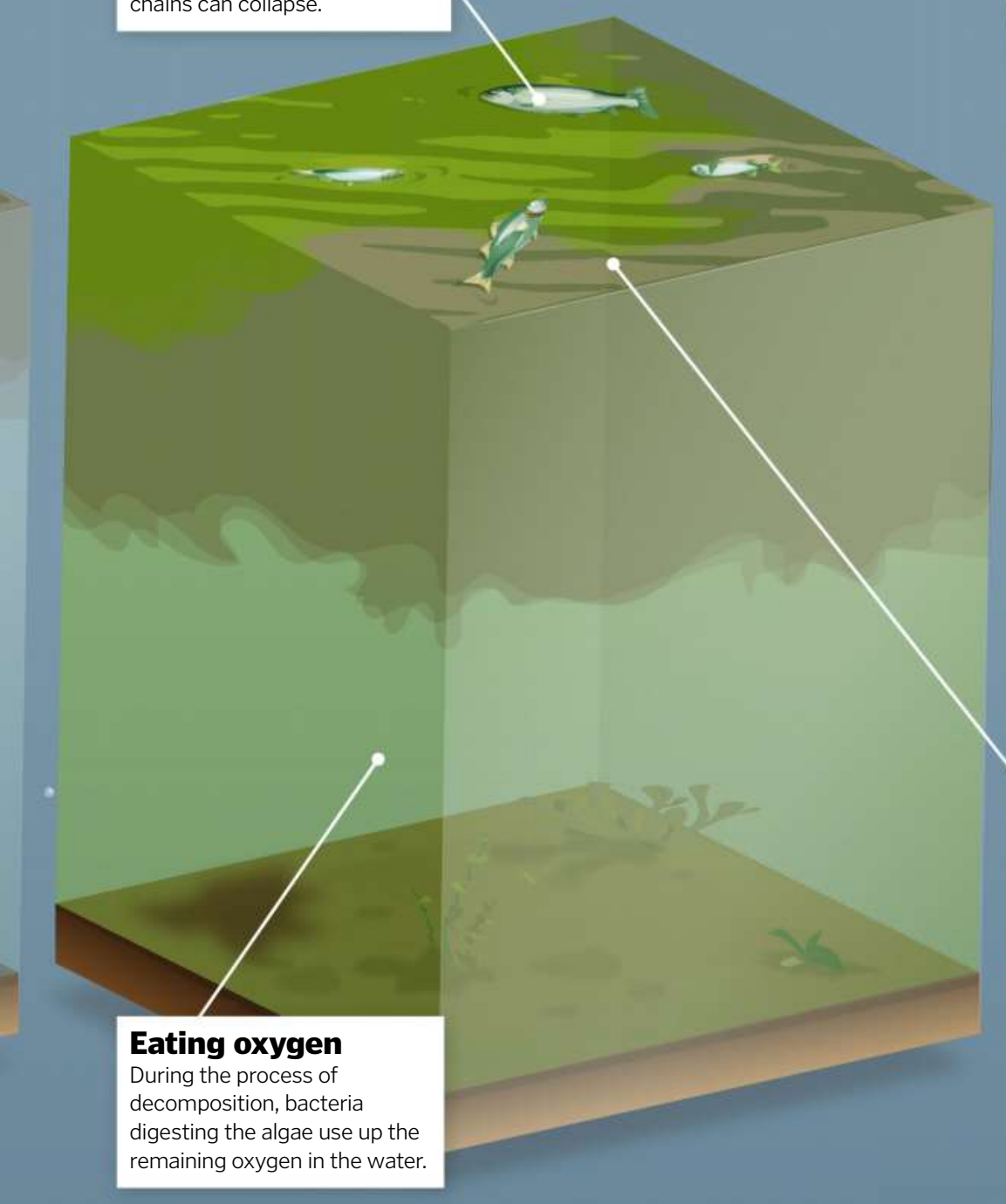
Dead zones, also known as hypoxic zones, are created when an influx of nutrients enters the water, promoting the growth of algae, seaweed and phytoplankton. As they continue to grow, they create an opaque blanket across the water's surface, plunging the seafloor into darkness. This prevents benthic plants from photosynthesising and dissolving oxygen into the water. The rapidly spreading algal blooms also eat up the existing oxygen in the water. As a result, marine life is stripped of a food source and the oxygen needed to survive, and many species die. This can have a massive impact on food chains. Without the plants and animals at the bottom of the chain, the species higher up also struggle to survive.

This is known as eutrophication. If you've ever seen a stagnant garden pond where the surface is covered in green algae, what you're

Salty graveyards

415 dead zones have been identified around the world, with some areas more heavily affected than others. For example, the Baltic Sea is home to seven of the ten largest dead zones on Earth. This map indicates coastal sites where human-added nutrients have caused a decline in oxygen levels that could have created dead zones.

Hypoxia
Once the oxygen has been stripped out by the algae, most marine species perish and food chains can collapse.



Eating oxygen
During the process of decomposition, bacteria digesting the algae use up the remaining oxygen in the water.

Oxygen barrier
Algal blooms can also prevent atmospheric oxygen from dissolving into ocean water.

© NASA Earth Observatory/Joshua Stevens

Blooms of phytoplankton coat the Baltic Sea every summer and are growing in intensity because of nutrient runoff

Dead zone giant

The world's largest marine dead zone is located in the Gulf of Oman, the northwestern arm of the Arabian Sea. A study in 2018 found that nearly the whole stretch of the 63,700-square-mile gulf is classed as a dead zone and is almost completely deprived of oxygen. This eutrophication event was first studied in the 1960s, and then again in the 1990s.

In the most recent study, researchers deployed remote-controlled submarines called Seagliders, which have instruments on board to measure the oxygen levels in the water. The data collected suggests that ocean warming as a result of climate change and agricultural fertilisers have created the Earth's biggest dead zone.

© NASA Earth Observatory

Taken 14 February 2015, this shows the Arabian Sea mixed with filaments of phytoplankton

seeing is eutrophication on a small scale. The word comes from 'eutrophos' – Greek for 'well-nourished' – but has become associated with areas of overnourishment to the point of destruction.

Dead zones can occur naturally, but more and more are being created by the agricultural activities of humans. Since 1950, dead zones in the oceans have quadrupled in size. In the process of growing crops, nutrient-rich fertilisers run off farming land and enter water systems, bleeding out into coastal waters. These fertilisers are often phosphate-rich, which algae lap up, blooming and spreading like wildfire. Other nutrients come from sewage that's dumped into waterways, and overfishing removes species that feed on algae.

To deal with eutrophication, task forces around the world are trying to reduce hypoxic zones. This is being done through different legal and practical strategies to reduce agricultural runoff. For example, the Mississippi River/Gulf of Mexico Watershed Nutrient Task Force was set up in 1997 to tackle a seasonal dead zone in the Gulf of Mexico, which measured 2,116 square miles in 2020. However, that was a massive drop from the 2017 figures, which measured the zone at a whopping 8,776 square miles.

What is sand?

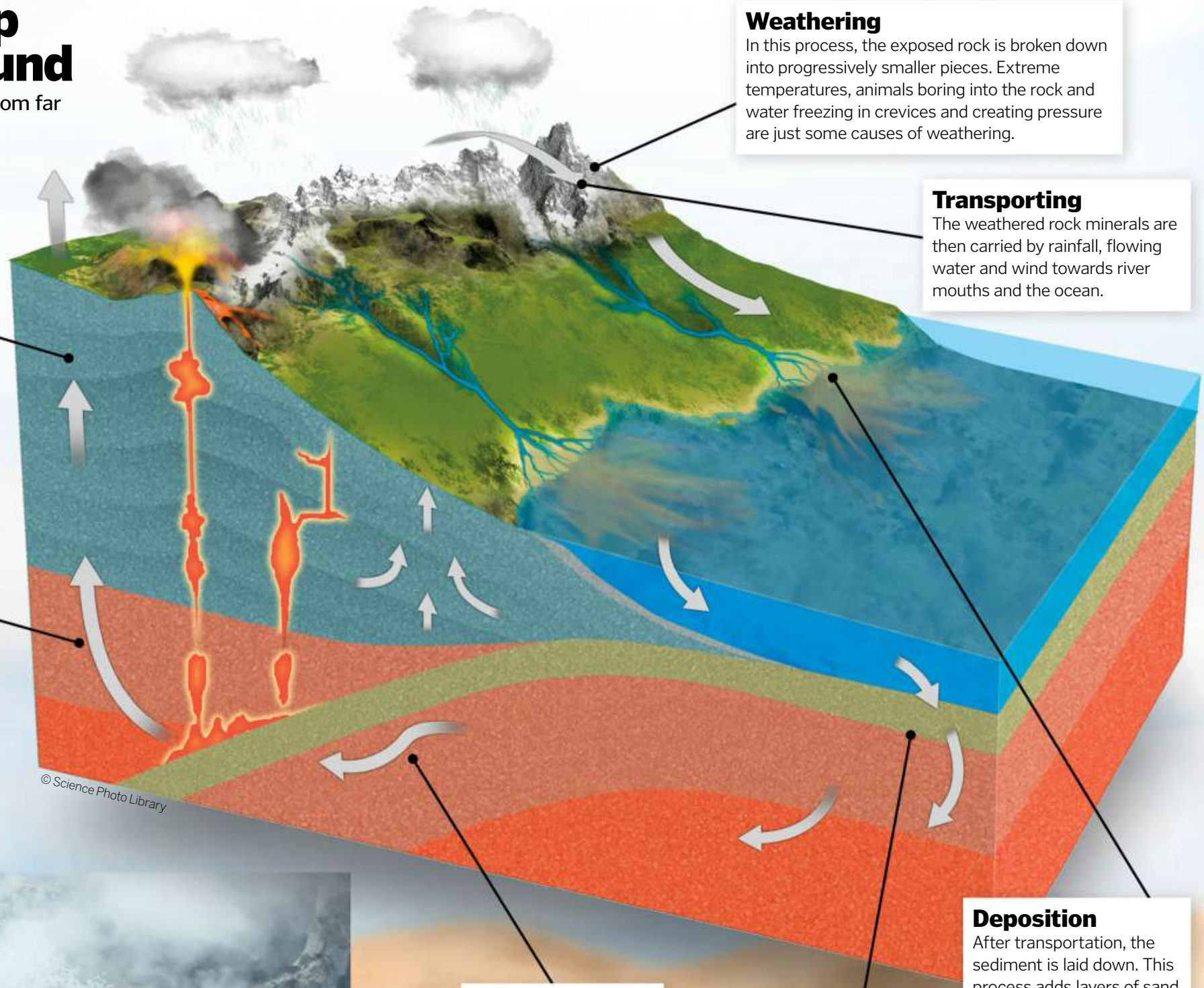
How the composition and disintegration of our rocky planet creates beaches

Blankets of sand cover vast areas of Earth's coastlines. They appear as uniform grains, making it look as though it all came from the same source. But a closer look reveals a variety of colours and shapes, each representing a different mineral composition. More often than not, the minerals that combine on a beach will result in the yellow tinge that we associate with sandy beaches.

Just as each grain differs from its neighbour, the qualities of sand on different beaches vary immensely. Local weather conditions and the shape of the coastline in an area can hugely influence the sand decorating its shores. Finer sand is often found in areas where low-energy waves lap at the land, while waves with more energy can carry larger sand particles and stones. Other weather conditions, such as wind strength, can also decide the size of the sand grains, with frequent wind spells blowing finer particles further from the water's edge. The flattest land often produces the finest sand, as the constant tides cause rock to move around, breaking the grains as they rub together. It's the constant movement of rock that brings sand into existence, replenishes our beaches and provides it with mesmerising characteristics.

From deep underground

How is sand delivered from far below Earth's surface?



Weathering
In this process, the exposed rock is broken down into progressively smaller pieces. Extreme temperatures, animals boring into the rock and water freezing in crevices and creating pressure are just some causes of weathering.

Transporting
The weathered rock minerals are then carried by rainfall, flowing water and wind towards river mouths and the ocean.

Igneous rock
Below 1,300 degrees Celsius, magma cools from its liquid form, becoming igneous rock. All of this rock will eventually become sand.

Magma crystallisation
Silica is the most common component of sand, made of silicon and oxygen. These are the two most abundant elements in Earth's magma, which cools from solid rock.

© Science Photo Library

Melting
Eventually the buried rock will melt, returning to the mantle.

Deposition
After transportation, the sediment is laid down. This process adds layers of sand and changes the shape of the land over time.

Burial
As rock is constantly eroded and sand layers added, grains are pushed downwards. As this happens, the sand becomes more compact. Pressure builds for lower layers, forming solid rock with the sand's minerals inside.

Watch as the ocean cools this lava, turning it into volcanic sand

© Getty

AR ZONE! SCAN HERE

Beach samples

Analysing grain shape, colour and material can tell us sand's type and source

© Alamy

Continental

Algarve, Portugal

This is the most common sand type, found on continental beaches. Usually a light brown and yellow colour, this sand contains a high volume of quartz grains and other minerals from the Earth's crust like feldspar.

© Alamy

Coral

Bermuda

Sand doesn't have to be made entirely of eroded rock. In some cases, beaches are created from dead animals and plants. Known as biogenic sand, this includes pieces of dead coral and animal exoskeletons.

© Alamy

Glass

Glass Beach, California

As glass waste enters the oceans, the pounding waves and grinding within the sand can turn these jagged shards into tiny pieces of rounded sea glass. This process can take between 30 and 100 years.

© Alamy

Lithic

Jade Cove, California

A form of immature sand. The rock is at an early stage in its weathering process – only partially broken down, with larger fragments. The more mature the sand becomes, the more uniform and rounded the rock pieces are.

© Alamy

Volcanic

Iceland

As volcanic lava solidifies and is broken up by the waves, or the basalt rock base is eroded onto the beach, the coastline becomes distinctively black. Pyroxene, magnetite and hornblende are the minerals that create these dark shades.

© Alamy

White silica

Australia

The brightest white beaches in the world contain large quantities of silica, produced from eroded quartz. Whitehaven Beach on Whitsunday Island in Australia, for example, contains sand of 98 per cent silica.

© Alamy

Garnet

Pfeiffer Beach, California

This sand sample contains mostly garnet, which is a red-pink mineral, combined with transparent quartz and green epidote. As a silicate mineral, it has a crystal structure and is usually common in sand in trace amounts.

© Alamy

Green

Papakōlea Green Sand Beach, Hawaii

This sand is from one of just four known green sand beaches in the world. The rare sand composition contains high volumes of the mineral olivine, which requires a volcanic eruption to bring to the surface in large quantities.

© Alamy

Ooid

Kleopatra Beach, Turkey

With ooid sand, each grain grows in size. Formed in warm, shallow waters, calcium carbonate in the sea crystallises onto the surface of these grains. In order to produce smooth, even spheres, the water needs to be in constant motion.

BRAIN DUMP

Because enquiring minds need to know...

MEET THE EXPERTS

Who's answering your questions this month?

JO ELPHICK

ANDY EXTANCE

ANDREW MAY

AMY GRISDALE

Our immune system weakens naturally with age, leaving older people more vulnerable to infections and cancer

SCIENCE

Can you boost your immune system?

Con Bruce

There are lots of ways to strengthen your immune response that are supported by science. Eating a diet high in fruit and vegetables and maintaining a healthy weight are vitally important to the immune system. Get enough sleep and exercise regularly. Don't smoke and keep your alcohol intake at a minimum. There are countless products available that claim to be immune boosters. We're still in the dark about which specific microbes are most helpful and how many of each we should have. The body already makes more immune cells than it can use. Medication designed to increase cell production may not be helpful in the long run, as excess cells simply self-destruct after a short time. **AG**

DID YOU KNOW?

Europa may contain more liquid water than all of Earth's oceans

© Alamy

WANT ANSWERS? Send your questions to...

How It Works magazine @HowItWorksmag @howitworks@futurenet.com

An AS350 Squirrel, similar to the one Delsalle flew to make his record-breaking flight

© A amy

TRANSPORT

Why can't helicopters fly up Everest?

Xie Wen

The forward flight of a helicopter is generally limited by the engine's ability to breathe the thinner air at high altitude. A helicopter with a powerful turbine engine might be able to reach around 7,500 metres altitude, which is nearly the top of Everest. But the maximum height at which it can hover – vital in mountain rescue missions – is much lower, around 4,000 metres, which is far below Everest Base Camp. In 2005, helicopter test pilot Didier Delsalle was able to land a Eurocopter AS350 Squirrel on the 8,848-metre summit of Everest by stripping unnecessary weight out of the aircraft and taking advantage of powerful updrafts. **BB**

In Coober Pedy, Australia, people often live underground to escape the heat

© Getty

TECHNOLOGY

Why don't we build houses underground to save space?

Bhavni Mehta

It's easier to build above ground. But people do build homes underground if there are reasons to do so, for example to keep cool in very hot places. Space is also an important reason. Somewhere between 150,000 and 2 million people live underground in Beijing, China – a very crowded city. Other cities considering building underground include Singapore and Mexico City. But many people don't like being underground, so underground homes should be carefully designed to be pleasant. **AE**

© Alamy

ENVIRONMENT

Could penguins live anywhere else but Antarctica?

Jenny Handsley

They can and do! Of the 18 species of penguin worldwide, only ten live in Antarctica. Of those ten, only the emperor penguin spends all of its time there. The rest are distributed throughout the Southern Hemisphere from New Zealand to the Falkland Islands. **AG**

© Getty

SCIENCE

Do potatoes have more vitamin C than apples?

Toby Howard

Potatoes are extremely healthy, and if eaten with the skin on can provide an adult with nearly half the daily recommended amount of vitamin C. That's about 14 per cent more than an apple. In fact, many nutritionists argue that the simple spud should be called a 'superfood' because of its health-inducing properties. **JE**

BRAIN DUMP

SPACE

Why don't planets twinkle like stars?

Kieran Burns

When light rays pass through the atmosphere, they get jiggled about by turbulence. We notice this jiggling with stars, which are just pinpoints of light, but not with more extended objects such as planets. The light rays come through different bits of the atmosphere, so the jiggling averages out. **AM**

© Getty

© Getty

SCIENCE

Why does condensation form on the outside of the windows in my house?

Alex Parkes

You probably have very well-insulated windows. They stop so much heat escaping that the outer glass pane stays cold enough that water vapour from the air condenses on it. **AE**

© Alamy

ENVIRONMENT

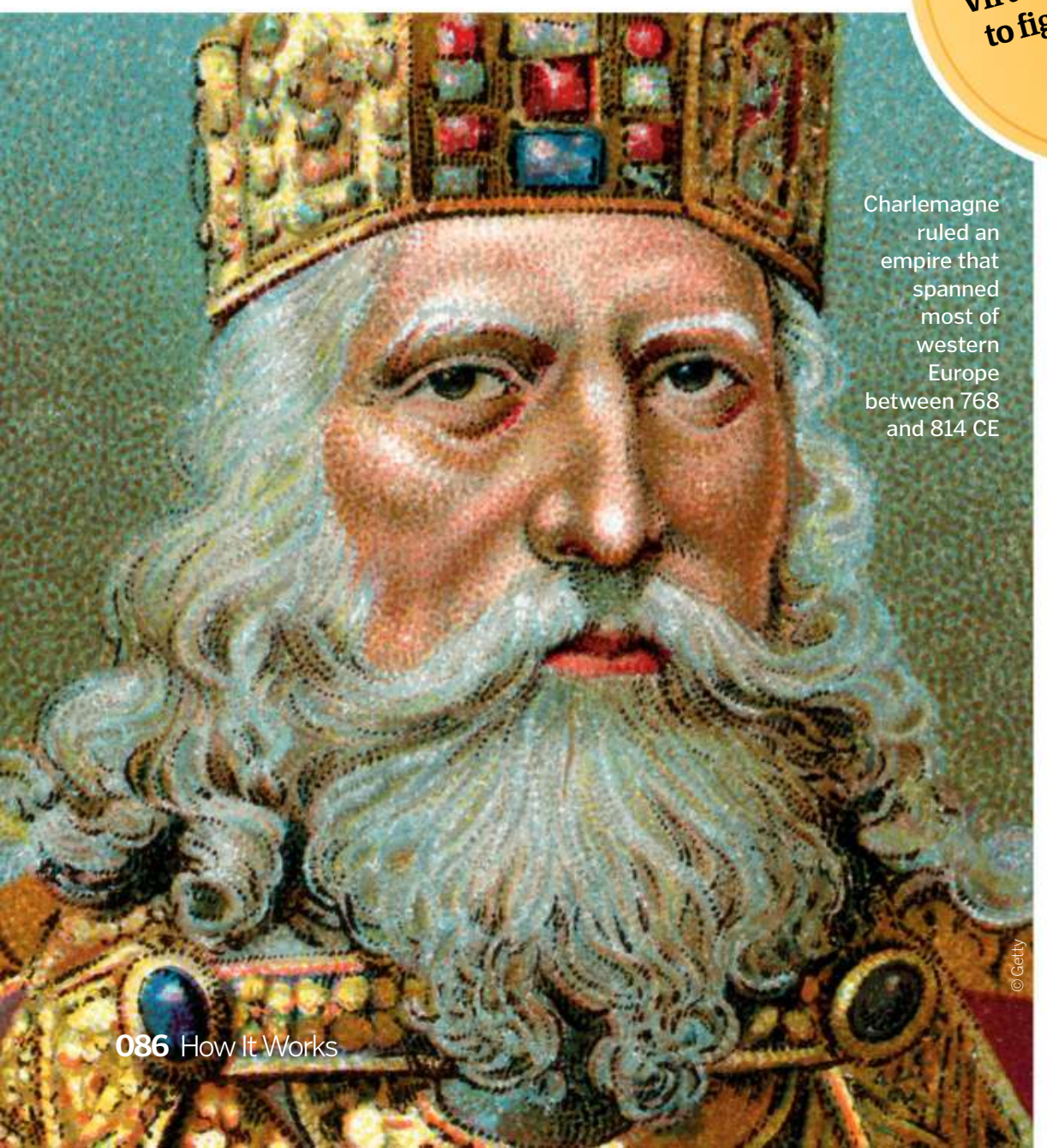
Why do seagulls grow so much bigger than other birds?

Ellen McGinn

Gulls are certainly larger than the average garden bird, and it's all to do with their environment. Garden birds live inland, while seagulls breed on sheer cliffs overhanging the ocean and would struggle to battle the wind and waves if they were the size of a sparrow. Having more body mass than the average bird helps gulls stay airborne in rough weather and float on the ocean, as well as giving them more food choices. Being a big bird also prevents some predators from attacking. Young seagulls grow to adult size very quickly to help them stay safe. **AG**

DID YOU KNOW?

Viruses can be harder to fight off when the body is cold



Charlemagne ruled an empire that spanned most of western Europe between 768 and 814 CE

© Getty

HISTORY

Are most people related to an ancient monarch?

Felicity Lane

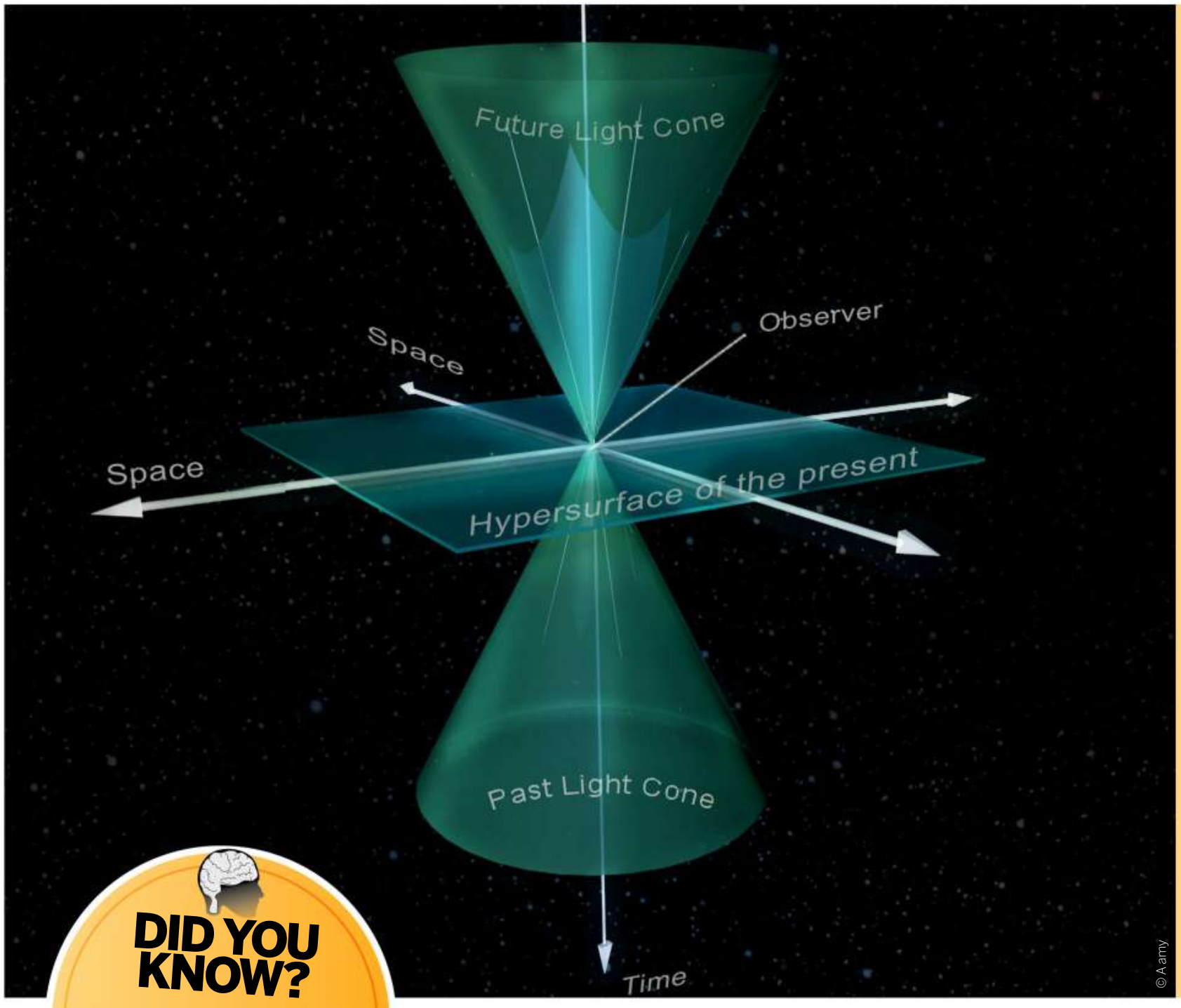
All Europeans are descended from Charlemagne, while all East Asians are descended from Genghis Khan. Quite simply, we are all related to an ancient monarch, no matter where we come from. **BB**

SPACE

What is the fourth dimension?

Reuben Butler

Everyday objects have three spatial dimensions at right angles to each other. A cubic box, for example, has length, width and height. It's possible to imagine a similar object, called a tesseract, which has a fourth dimension at right angles to the first three, but imagination is as far as it goes. Tesseracts don't exist in the real world, which as far as we know only has three spatial dimensions. However, Einstein's equations of relativity treat time in a similar way to those three dimensions, so physicists often talk about a space-time continuum in which time is the fourth dimension. **AM**



A simplified representation of four-dimensional space-time, showing time running along the vertical axis

© A army

DID YOU KNOW?

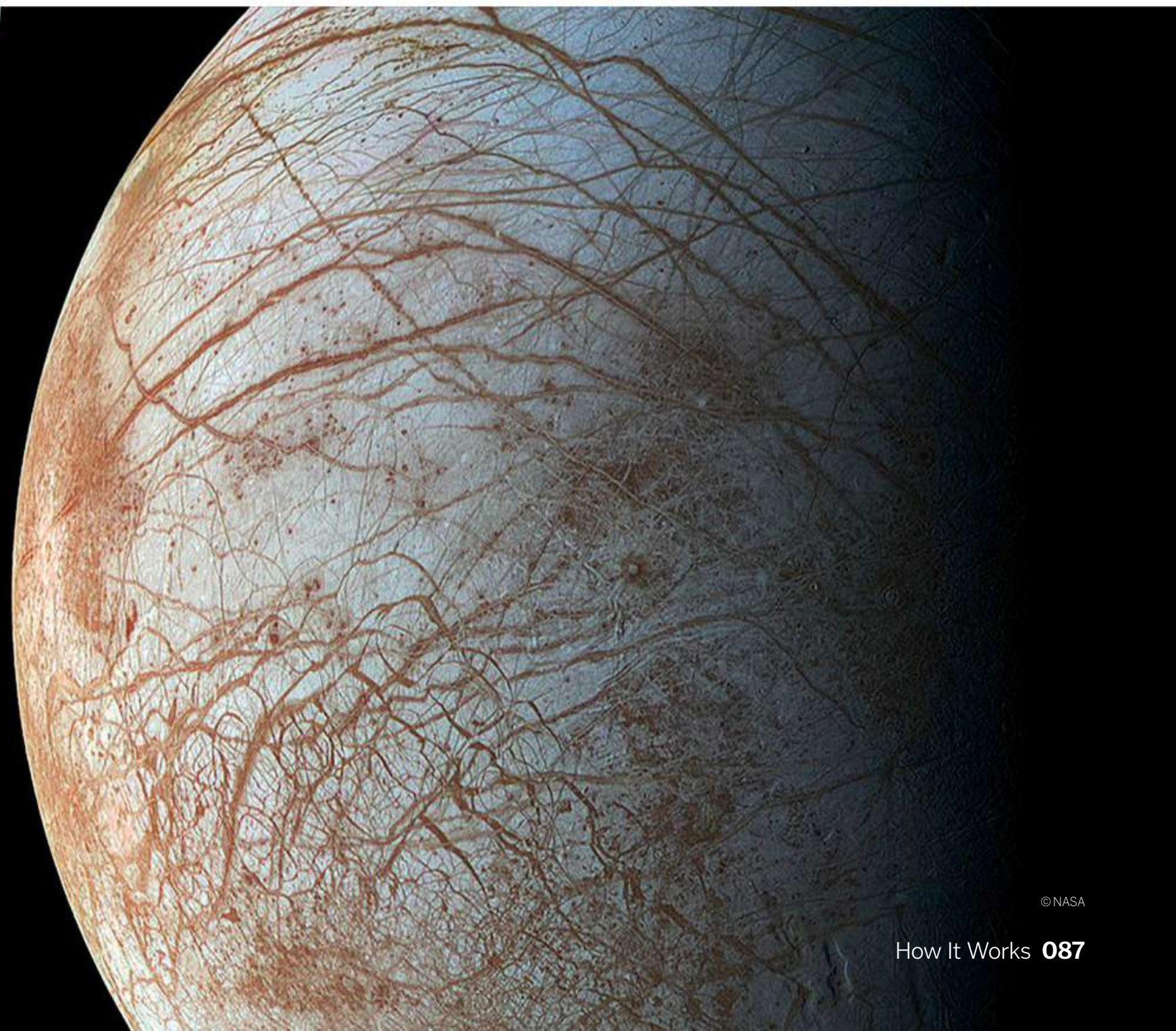
Japan's Fugaku supercomputer can make 415 quadrillion calculations per second

SPACE

Could there be life on Europa?

Sarina Humphries

Yes, there might well be. Europa's subsurface ocean has all the ingredients for life: water, nutrients and heat. But we have no evidence yet that there actually is life there. **AM**



© NASA

BRAIN DUMP

ENVIRONMENT

If the world's ice caps melted completely, would all the land be covered in water?

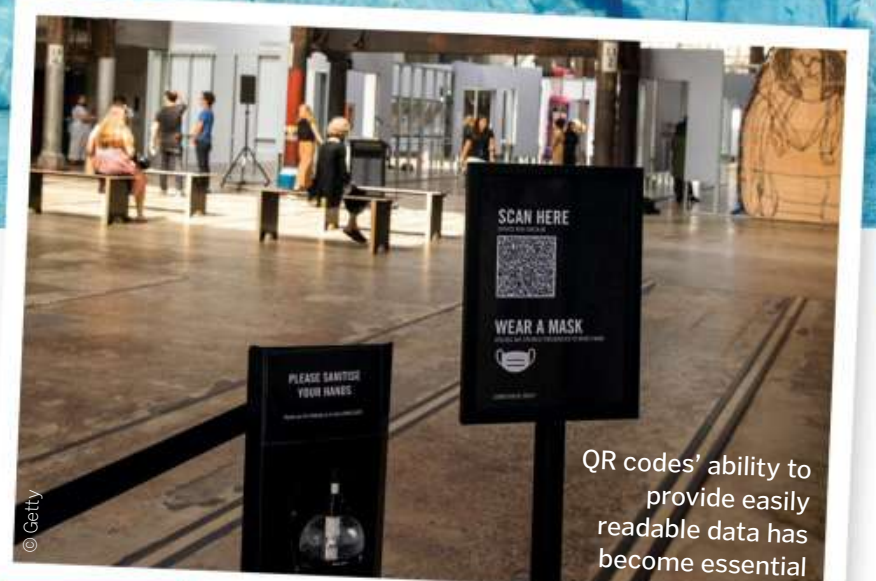
Matthew Bradbury

Scientists have calculated that if every scrap of natural ice on Earth melted, sea levels would rise by about 70 metres. Low-lying areas would be flooded, but inland cities with some elevation, such as Denver, Colorado, would survive. **AG**

© A amy

DID YOU KNOW?

The 20-kilogram kori bustard is the world's heaviest flying bird



© Getty

QR codes' ability to provide easily readable data has become essential

TECHNOLOGY

How does a QR code work?

Chris Butt

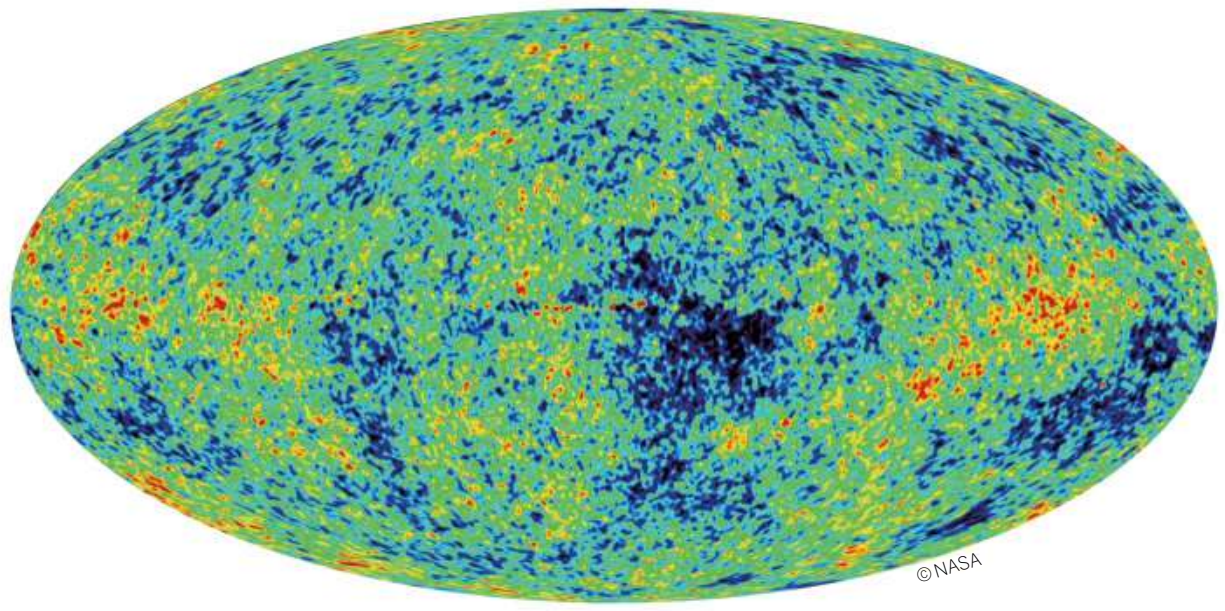
Quick Response (QR) codes rely on our mobile gadgets' computing power to get data out of a block of black and white squares quickly. The camera on a phone or tablet recognises big squares at three corners of the QR code, and smaller squares near the fourth, to be able to figure out its position. Our gadgets can then read out codes from the picture – for example with white squares as zeroes and black squares as ones – and also correct any errors. There are many different systems that people can use to translate these zeroes and ones to useful information. **BB**

SPACE

If we looked really far into space, could we see the Big Bang happening?

Franziska Bachman

It's true that the further we look into space, the earlier we see in time. Around 380,000 years after the Big Bang, however, the universe was filled with super-hot plasma that scattered light, analogous to the way clouds scatter sunlight. Just as we can't see above the cloud base, we can't look further back in time than the so-called 'surface of last scattering'. It is here that the cosmic microwave background originates. **AM**



©NASA

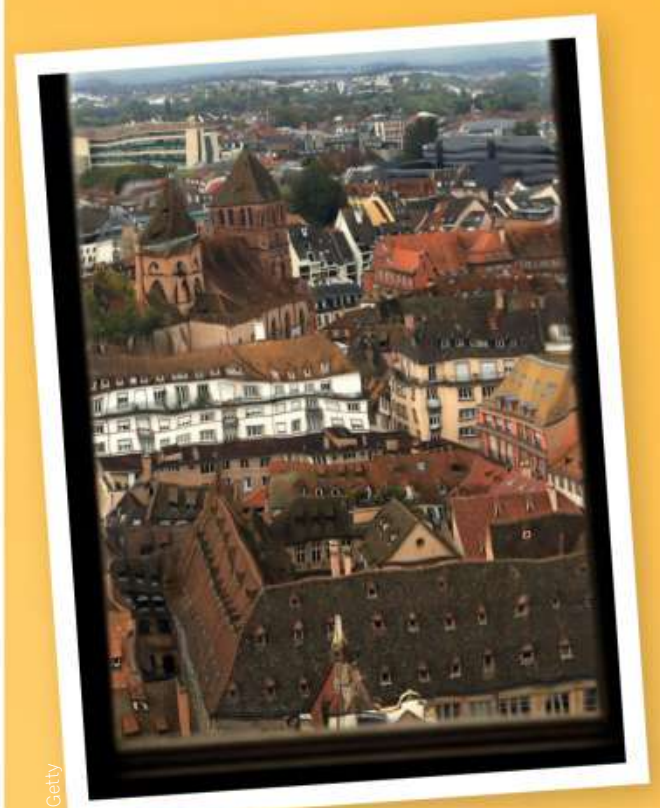
© Getty

TECHNOLOGY

Is there a need for physical money today?

Andy Masters

There are many ways to pay for things without using cash, from contactless payments to chip-and-pin credit cards, so will bank notes and coins simply disappear? The answer is almost certainly no, at least not for the time being. Cash is stable, unlike cryptocurrencies like Bitcoin. It is also untraceable, which might occasionally prove useful. Notes and coins are globally reliable and ultimately convenient. The internet may crash, but you can still pay with cash. **JE**



© Getty

SCIENCE

Does glass really slide down to the bottom of the window pane?

Jeff Jacobs

Some old windows are thicker at the bottom. It's true that glass, as an amorphous solid, can flow downwards a little bit. But it can't flow enough to explain the extra thickness. Instead the fat-bottomed windows typically originate from panes being uneven because they were made from cylindrical glass ingots. **AE**

HISTORY

What was law enforcement like in the UK before the police were invented?

Jacob Farthing

Before the arrival of the modern-day police force, law enforcement was erratic since it was left entirely to local communities, with each area dealing with criminal behaviour in its own way. Across the Middle Ages, locals relied upon 'hue and cry', a system whereby someone who witnessed a crime would shout out and all the local men would band together to track down the criminal. This was overseen by a constable, who acted in an official capacity despite not being paid. Nightwatchmen patrolled the city streets, but they were unreliable, often drunk and could be paid off by wealthy criminals. JE

The unreliable nightwatchman yawns as burglars make their escape behind him

© Getty

DID YOU KNOW?

Glaciers can form even on tropical mountains

TECHNOLOGY

What are supercomputers for?

Ria Macintosh

The most advanced of these giant computing machines perform millions of times more calculations per second than today's average desktop PC. Today they're used to solve vastly complex problems in a number of industries, including accurate weather forecasting, pandemic outbreak simulations and vaccine development, creating true artificial intelligence and much more. Quantum computers are the next technological step in processing data: this new wave of machines will be orders of magnitude more powerful than modern supercomputers. **BB**

© Getty

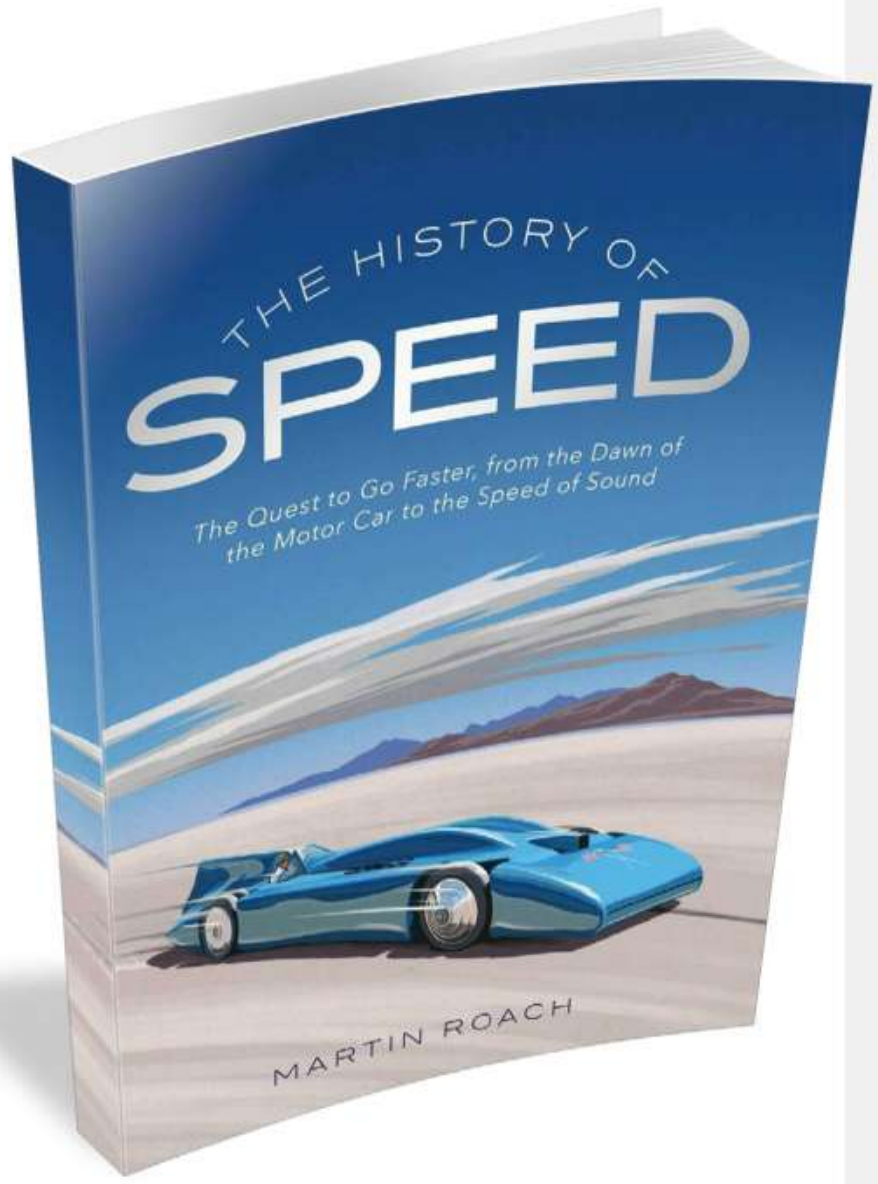
BOOK REVIEWS

The latest releases for curious minds

The History of Speed

THERE'S NO SUCH THING AS TOO FAST

- Author: **Martin Roach**
- Publisher: **Simon & Schuster**
- Price: **£25 / $46.66**
- Release: **Out now**



Roach packs this coffee-table hardback with all the stats and facts

Breaking land speed records is a curious profession to most people who stay safe and comfortable in their daily lives. Actively pursuing activities that have a high risk of serious injury or death can seem like a perverse pastime, but that doesn't stop millions of motorsport fans from watching the F1 Grand Prix every year. And neither did it put millions more off supporting the ThrustSSC team in the pursuit to develop the world's first supersonic car in 1997, when it set a land speed record of 763 miles per hour – a record that still stands over 20 years later.

Bestselling author Martin Roach is a speed nut who has been following motorsport and the bleeding edge of competitive racing for decades. In *The History of Speed*, he brings his vast knowledge of the automotive industry and a passion for the adrenaline thrills of record-breaking vehicles together. Chronicling the people, vehicles and places that have become legendary over the last century or so, Roach packs this coffee-table hardback with all the stats and facts that *How It Works* readers love to learn about. For example, what it feels like to crash in a vehicle that's travelling at over 360 miles per hour, who was given the world's first speeding ticket and how a record-breaking car can generate temperatures in its engines that equal the inside of an active volcano.

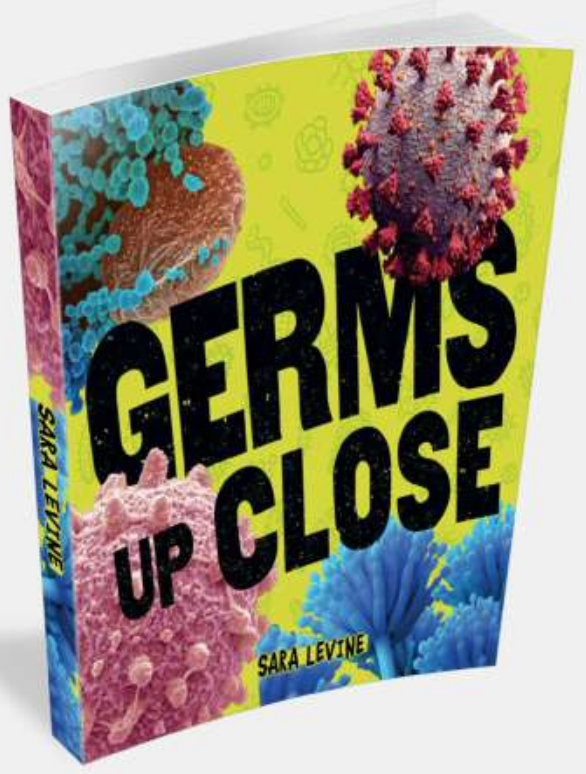
The History of Speed is liberally illustrated with photos, sketches, posters and newspaper clippings for a real sense of the zeitgeist in each era. Roach has also interviewed big names and legends of speed, including ThrustSSC's project director Richard Noble OBE, who talks in detail about the psychology of speed: why the risk of death makes him feel alive, how people deal with fear and what compelled him to break the world land speed record… twice. It's an easy read and surprisingly deep. *The History of Speed* is much more than just a bible for petrolheads.

Germs Up Close

ZOOM IN ON THESE MICROSCOPIC CELLS

- Author: **Sara Levine**
- Publisher: **Millbrook Press**
- Price: **£19.79 / $27.99**
- Release: **6 April**

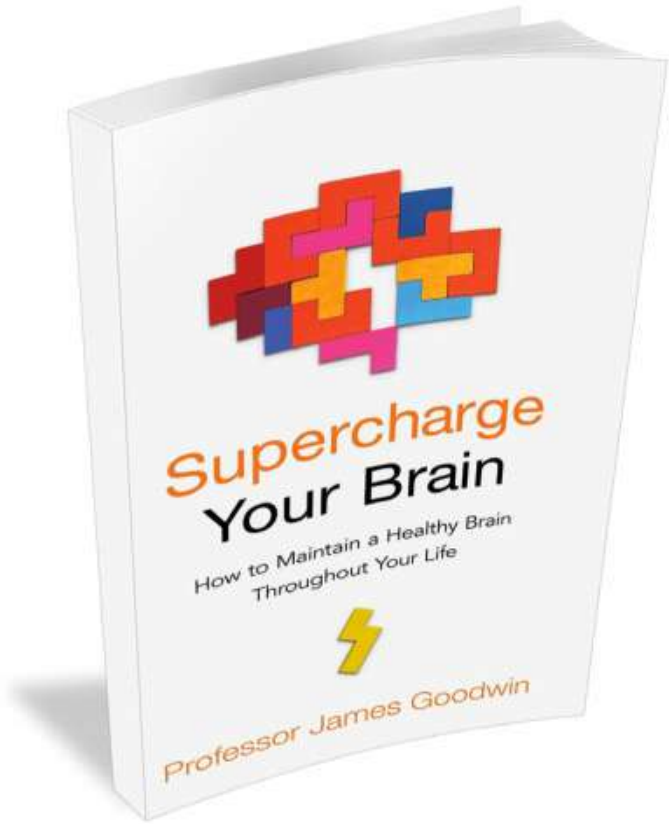
What does a germ look like? Most children are taught about what a germ is, but many will never have seen one due to their tiny size, or even know where to start when imagining them. This book provides curious young minds with mesmerising images. Instead of inducing fear in the reader, Levine explains both the dangers of bacteria, viruses, fungi and protozoa and the incredible diversity that can be found in this unseen world. Each page takes a look at a new species and explains their appearance, role and where they can be found using child-friendly language. As well as highlighting the damage that these germs can do, this book explores how efficient our bodies are at fighting them. You will be introduced to your body's defences – white blood cells and friendly bacteria – and you will learn about the importance of handwashing and vaccines. This vibrant, image-led book will teach primary school children the fascinating facts about a crazy world – one which they may not have been aware was living alongside them.



Supercharge Your Brain

THE NEW SCIENCE OF HOW TO STAY SHARPER FOR LONGER

- Author: **James Goodwin**
- Publisher: **Bantam Press**
- Price: **£14.99 (approx. $21)**
- Release: **1 April**



Your brain carries out so many complex roles in every second of every day. It's the organ that makes us unique, keeps our bodies functioning and houses our every thought. But despite being the maker of our memories, the importance of looking after our brains can be easily forgotten.

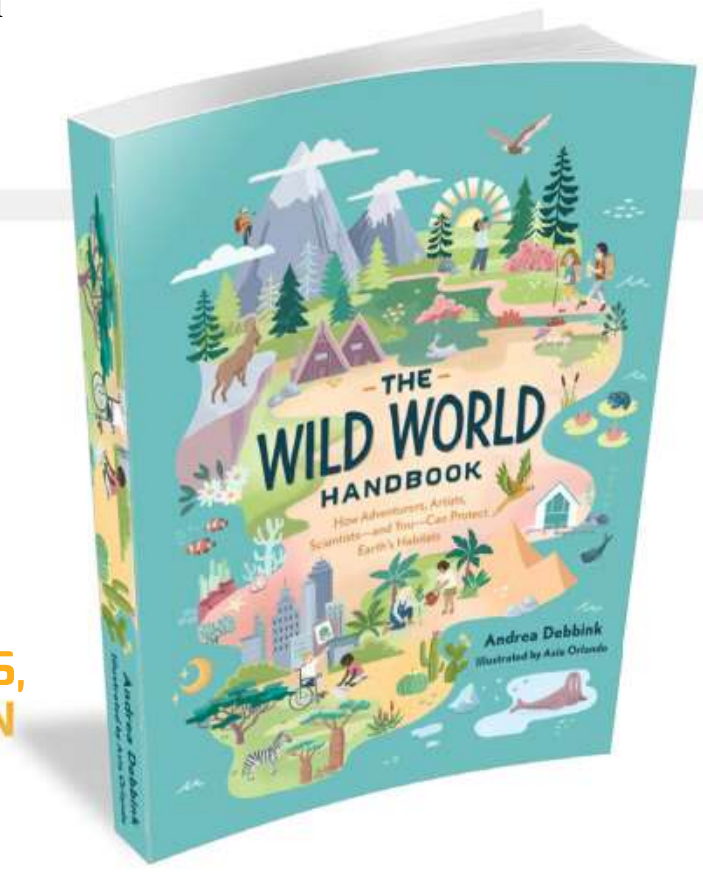
In this book, Professor James Goodwin delves deep into some of the latest scientific findings, forming intriguing and varied chapters. Each page is packed with the most relevant information on how to maximise your brain health. Why should we take regular breaks from our office chairs? How were our ancestors' brains boosted by intermittent fasting? And why should you drink before you start feeling thirsty? These are just some elements of our lifestyle affecting our brains.

Although this book is called *Supercharge Your Brain*, it focuses on the entire biology of the human body, taking you on a gripping journey to knowing yourself better. As well as covering the benefits of puzzles and how to keep your brain alert directly, you will learn how the care you provide to other areas of your body has an impact on your brain health. With a summary of rewarding tips to take away from each section, this book is a great way to make better informed choices about your body and brain. It serves as a perfect reminder of how vital and connected this complex organ really is.

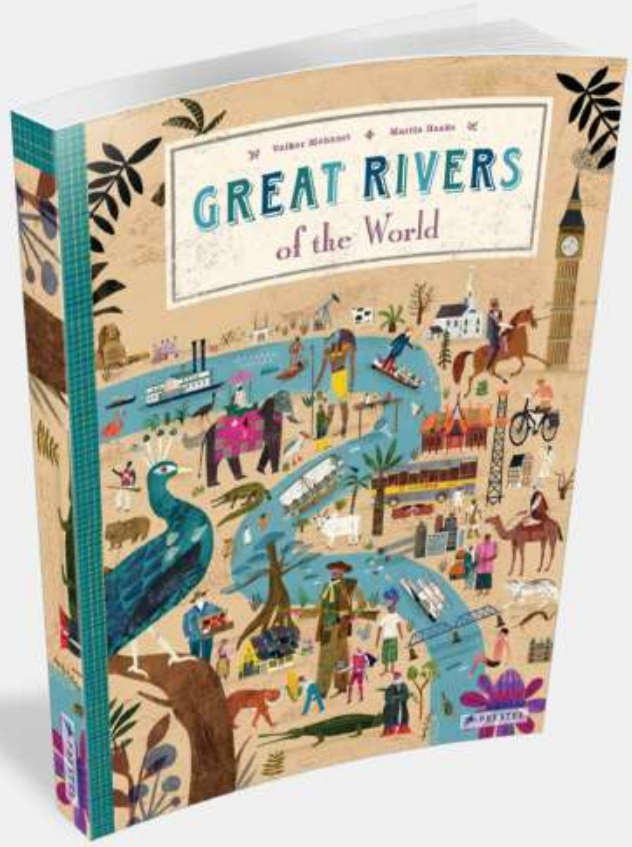
The Wild World Handbook: Habitats

HOW ADVENTURERS, ARTISTS, SCIENTISTS – AND YOU – CAN PROTECT EARTH'S HABITATS

- Author: **Andrea Debbink**
- Publisher: **Quirk Books**
- Price: **£15.99 / $20.48**
- Release: **25 May**



Mountains, forests, deserts, polar regions and more – this book explores habitats around the world through the interesting stories of those that dedicated their lives to protecting and studying them: the brave mountaineer Junko Tabei, brilliant botanist George Washington Carver, Arctic survivor Ada Blackjack and many more. Offering suggestions on 'ways to care', this book calls its readers into action to help preserve the world's many habitats through both at-home and wider reaching methods, such as how to write to your local government and how to organise a waterway clean-up. It also includes some fun and interactive at-home projects, including how to make a hiking stick and a desert biome. Although it's clear this book is aimed at a younger audience, its content – particularly the biographies – is a great read for the whole family.



Great Rivers of the World

DISCOVER HOW RIVERS HAVE SHAPED THE WORLD WE LIVE IN

- Author: **Volker Mehnert**
- Publisher: **Prestel**
- Price: **£14.99 / $19.95**
- Release: **Out now**

From the Mississippi River to the Egyptian Nile, sail down the world's waterways in this beautifully illustrated guide. This book explores 18 rivers from almost every continent on Earth and dives into the roles each one has played in shaping the communities beyond their banks. From the African manatees that dwell in the mangrove swamps of the Congo River to the towering metropolis built around the River Thames, this book provides insightful nuggets of information about river ecology and its historical and cultural significance in a fun and illustrative way. Written to educate a younger audience on the impact of rivers, *Great Rivers of the World* also focuses on the importance of keeping these waterways and their surrounding habitats healthy, and what the dangers of losing them could be.

"A beautifully illustrated guide"

BRAIN GYM

GIVE YOUR BRAIN A PUZZLE WORKOUT

QUICKFIRE QUESTIONS

Q1 What type of animal is a Tasmanian devil?
- Marsupial
- Arachnid
- Reptile
- Bird

Q2 What was famously excavated at Sutton Hoo in England?
- A *T. rex* skeleton
- An ancient ship burial
- A medieval crypt
- A WWII bomber

Q3 What chemical compound is chalk?
- Calcium hydroxide
- Carbon dioxide
- Hydrogen oxide
- Calcium carbonate

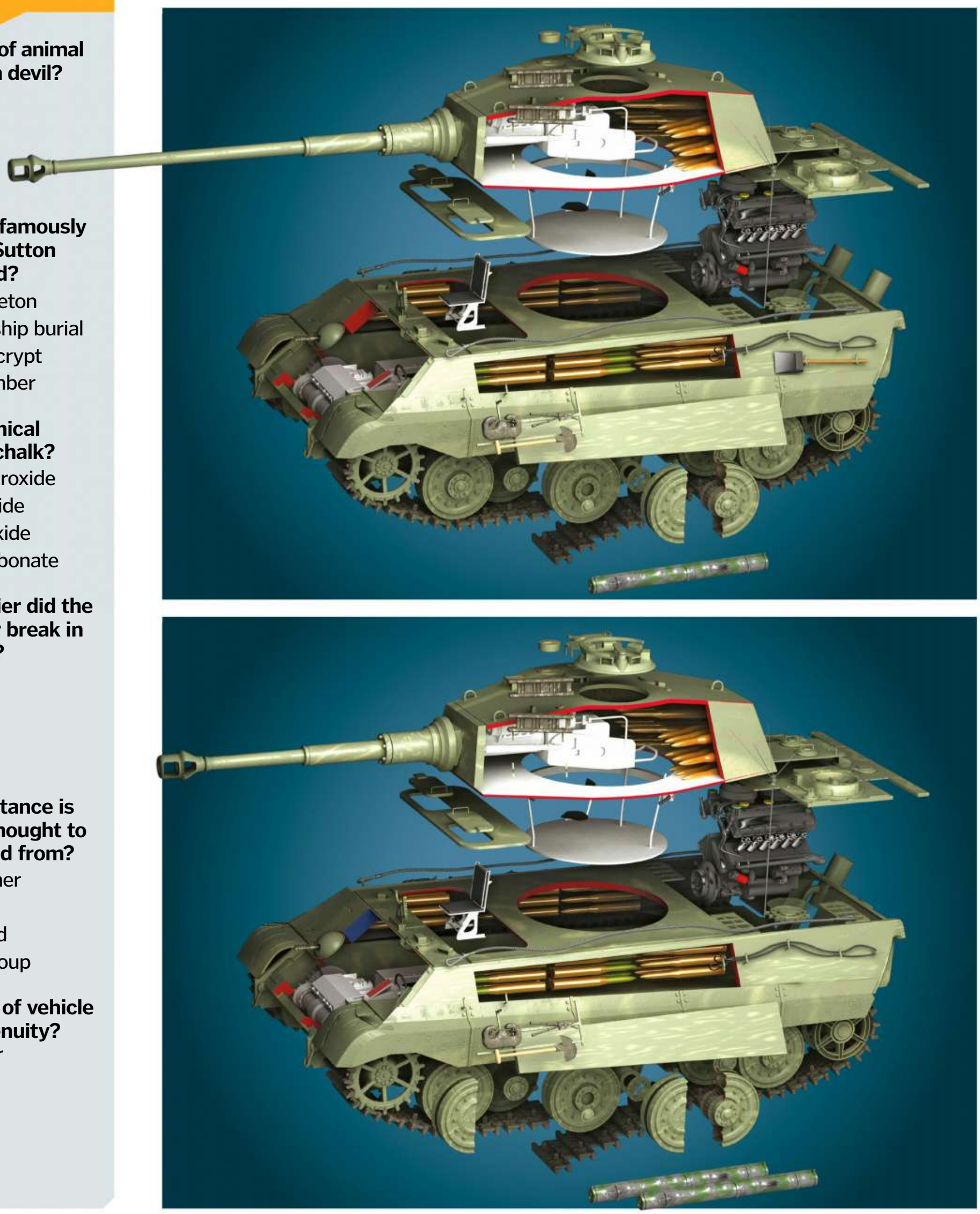
Q4 What barrier did the ThrustSSC car break in October 1997?
- Sound
- Light
- Reef
- Berlin Wall

Q5 What substance is life on Earth thought to have originated from?
- Ancient dinner
- Old meal
- Jurassic food
- Primordial soup

Q6 What kind of vehicle is NASA's Ingenuity?
- Tunnel borer
- Ambulance
- Submarine
- Helicopter

Spot the difference

See if you can find all six changes between the images below



Sudoku

Complete the grid so that each row, column and 3x3 box contains the numbers 1 to 9

EASY

	3	2	6				4	9
6			9	3	2	1	7	
		8	4		5	3	2	
4		5	1		6		8	
			2					
			3	9		2		
	1	6	8	4		7	9	
2	9			6	1			4
		3	7				5	1

DIFFICULT

8		4	6					
			9					
	5		3	8	1			4
6		9					2	
		1	2					8
				3	4			7
	7				5			
					3		1	
	2		8			7	6	

© Getty

What is it?

Hint: You might find this tiny insect at a market...

A .....

Wordsearch

FIND THE FOLLOWING WORDS...

A	Z	O	I	D	B	I	M	A	G	E	K	C	A	S
S	X	A	L	I	E	N	E	G	H	C	I	E	P	C
E	B	T	G	U	N	P	L	O	V	U	N	X	I	H
L	O	X	L	E	X	C	I	A	G	I	E	C	U	O
W	T	R	A	N	S	F	O	R	M	E	R	A	E	O
Z	Y	C	S	A	L	E	R	T	M	E	B	V	F	L
J	H	I	S	A	N	F	O	E	B	S	I	A	Z	P
N	I	R	E	O	O	L	R	S	U	N	K	T	E	H
E	Y	X	S	E	W	B	E	A	G	A	K	I	D	K
K	T	B	I	N	F	S	G	U	E	H	V	O	X	B
N	L	R	E	X	C	A	H	W	A	L	R	N	I	P
U	Q	C	K	O	O	N	L	E	X	J	C	U	L	R
S	A	O	I	H	E	D	W	Y	O	B	I	U	L	O
T	W	O	B	E	E	S	D	I	B	N	U	C	N	X
H	E	B	E	N	S	Z	I	F	X	O	J	S	C	H

TRANSFORMER
SAND
NUCLEAR
SCHOOL
ALIEN
GLASSES
BEES
EXCAVATION
OIL
XBOX
AGE
SUNKEN

Check your answers

Find the solutions to last issue's puzzle pages

SPOT THE DIFFERENCE

QUICKFIRE QUESTIONS

Q1 107 billion
Q2 A marine animal
Q3 13.2° Celsius
Q4 81 million years
Q5 13,200mph
Q6 G-type

WHAT IS IT? ...A BRAIN

© Getty

HOW TO...

Practical projects to try at home

Get in touch

Send your ideas to...

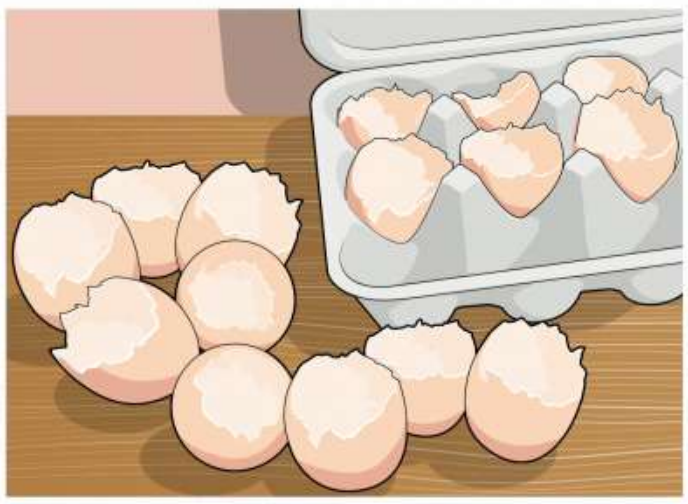
- How It Works magazine
- howitworks@futurenet.com
- @HowItWorksmag
- howitworksmag

HAD A GO? LET US KNOW!

If you've tried out any of our experiments – or conducted some of your own – then let us know! Share your photos or videos with us on social media.

How to make eggshell chalk

Use these simple ingredients to turn your food waste into street art

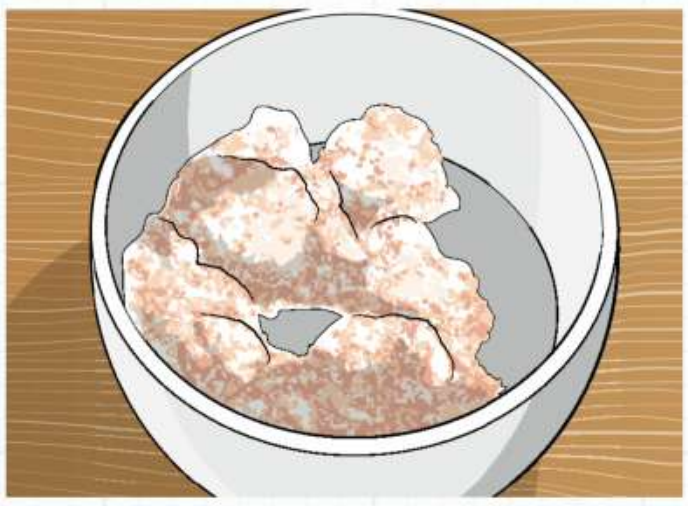


1 Prepare the shells

Thoroughly wash ten eggshells, taking care to remove the inside membrane. Once completely dry, place them into a mortar. You can also use a bowl and rolling pin, or even a rock and concrete.

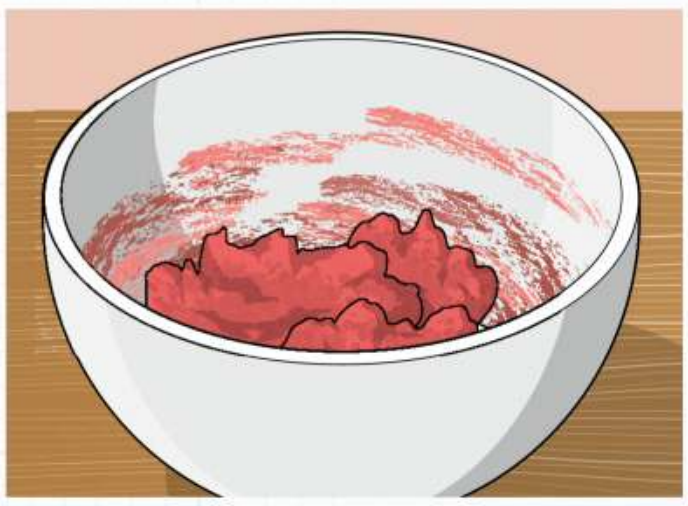
2 Keep it fine

This is where the hard work comes in. Crush and grind the shells until they become a very fine powder. Once your shells are broken into the smallest possible pieces, place them into a bowl.



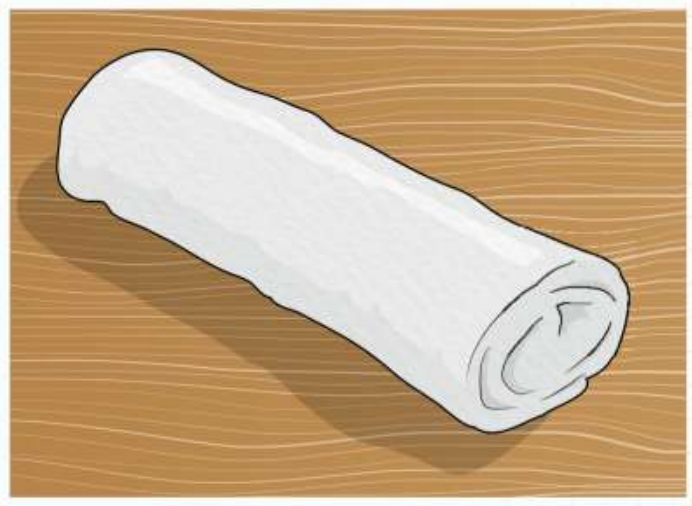
3 Make a paste

Add two teaspoons of flour and four teaspoons of hot water to your bowl of eggshell powder. This should create a thick paste when mixed together.



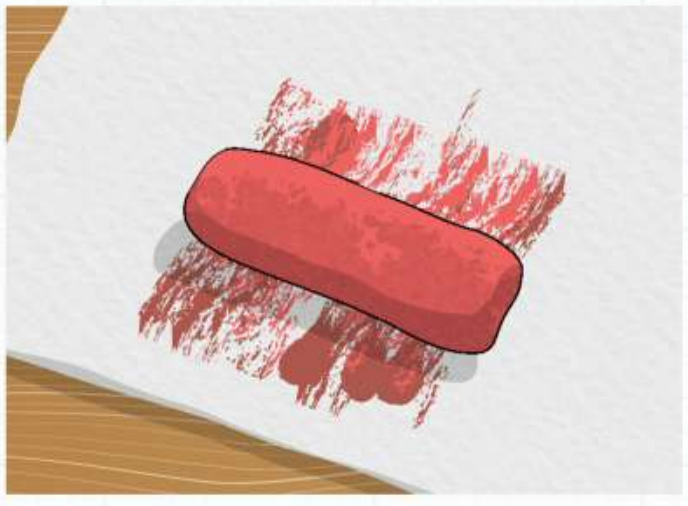
4 Add some colour

Decide which colour you would like your chalk to be, and add food colouring to your paste. Make sure this is mixed in evenly to keep your chalk consistent.



5 Mould the chalk

Place the mix into the centre of a paper towel and roll it into a long tube shape. Or if you have silicon moulds in the kitchen, you can use these to create interesting shapes.



6 Leave to set

Now that you are happy with the shape, you might want to test the chalk straight away, but it isn't ready yet! You will need to leave your chalk to dry out for about five days.

7 Be creative!

Once dried, your chalk is ready to test. Although the eggshell consistency won't work on a regular blackboard, these sticks are ideal for a fun outdoor activity.

SUMMARY

The main ingredient of chalk is calcium carbonate. For shop-bought chalk, this ingredient is added during manufacturing. However, chalk is also made in the sea with natural materials. It's formed when the shells and skeletons of tiny marine animals fall onto the seafloor. Here they are broken up into tiny pieces, producing the same consistency that you have created with your eggshells. About 95 per cent of a dry eggshell is made of calcium carbonate.

NEXT ISSUE... Make your own pH testing kit

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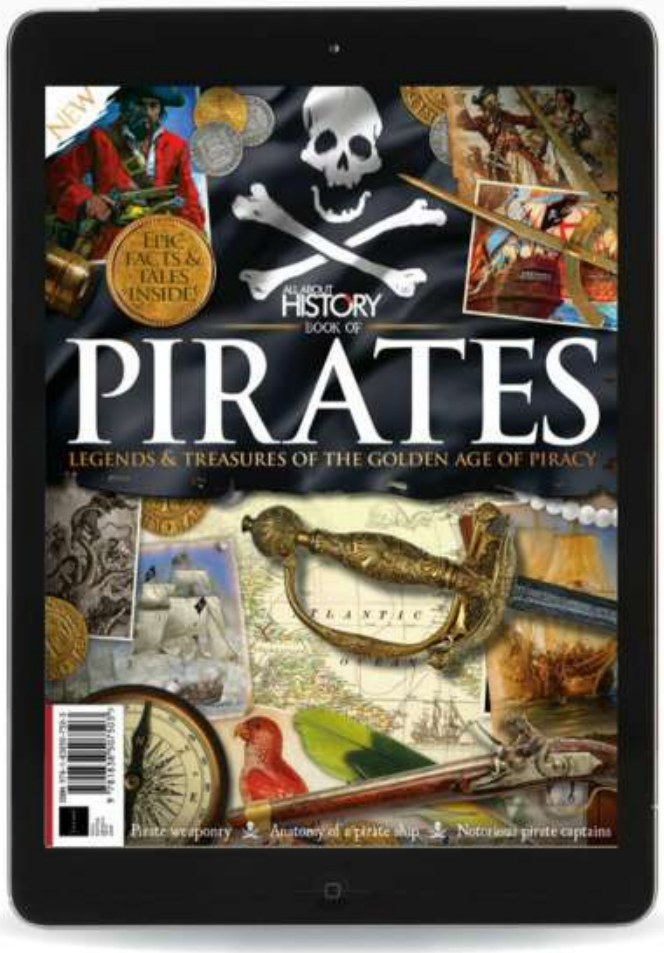

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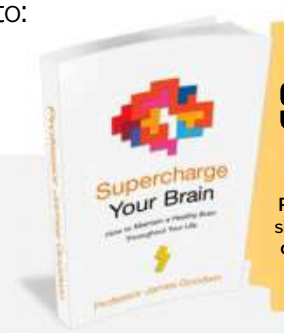

WIN!
SUPERCHARGE YOUR BRAIN
Professor James Goodwin reveals simple lifestyle tricks and tips that can transform the health of your brain and keep your mind sharp across your whole life.

© Getty

By absorbing more heat, darker hair also stops more of the Sun's radiation from passing through to the scalp

Hot headed

Hi **HIW,**

How come black-haired people's heads get hotter than blondes? Me and my friend noticed that my head was hot every time the Sun shone on it for a long time, while my blonde friend never had a problem.

Lezeiram

This is a good question Lezeiram, and it is all to do with why we see different objects as different colours. Black and dark-coloured objects absorb more of the light from the Sun, while lighter coloured objects will reflect more of its wavelengths. These wavelengths of visible light are what we see when we are observing colour.

When talking about hair colour, your darker hair is much better at absorbing light from the Sun and converting this into heat energy than your friend's. Blonde hair will only absorb some light, reflecting the rest away from the head. When spending the same amount of time standing in the Sun, your head will retain more heat and get warmer than a blonde person's.

LETTER OF THE MONTH

Wild art

Hi **HIW,**

I'm Tisha, an Italian wildlife artist. I have been painting animals endemic to my land, Sardinia, and endangered animals. I hope you like these paintings and you share one of them in your letters page.

At the moment I am painting common and endemic Sardinian species. I have been studying their characteristics and the factors that contributed to their development and conservation. I brought the species and characteristics that struck me the most back to the canvas. The goal of my work is to pay homage to these wild and wonderful creatures and celebrate them.

Tiziana Sanna

Thank you for sharing these paintings with us. It's clear from seeing your collection that you are both a talented painter and passionate about your local wildlife. Being an island, Sardinia is a prime location for endemic animals – species that are unique to one region, often because they are geographically isolated.

When separated from the rest of their species for long periods of time, animals can begin to evolve differently, breeding only with those on their island. Eventually, sometimes after millions of years, two groups of animals that used to be the same can change into new species.

Sardinia broke away from mainland Europe 30 million years ago. As the island later became populated, its inhabitants congregated in specific areas, leaving a large area untouched. This has helped to preserve some of these species by providing them with an area to continue living alongside humans. However, as the population of Sardinia has increased in recent years, it is important to raise awareness of the rarity of these animals, and your work is a captivating way to do so.

The Tyrrhenian lizard is endemic to Sardinia and Corsica

Tiziana has painted many endangered animals to raise awareness

© Tiziana Sanna

Identical twins form from the same egg, sharing genetic information

© Getty

Identical development

Dear **HIW,**

Would an identical twin develop appendicitis if the other one does? If so, would it be around the same time or age for both of them?

Antonio

Sometimes twins can be more susceptible to the same illness because they share the gene that makes them more likely to develop it. However, appendicitis is the swelling of the appendix due to infection. Mainly caused by bacteria, viruses or parasites that enter an individual's intestine, its cause is believed to be environmental. If twins had genes that made them more susceptible to developing appendicitis, this doesn't mean that they will both suffer from it, and if they do then it would be extremely rare for this to occur at the same time. Appendicitis mostly affects people between the ages of 10 and 20.

Lockdown learning

Dear **HIW,**

Like many parents, I have been homeschooling my son during the lockdown, and he's been learning about the properties of different minerals. It made us wonder, why are diamonds so hard? We are looking forward to your answer.

Kaitlin Mason

High temperatures and pressures can completely transform the appearance of carbon

Diamonds form about 100 miles below the Earth's surface. In the insanely hot and high-pressure environment of the upper mantle, carbon atoms crystallise to form diamond. As a result of this process, molecules are moved closer together, stopping them from moving. This tightly bonded structure has an incredibly strong arrangement of atoms. Each carbon atom is attached to four others, resulting in a rigid network. The hardness of crystals is measured by their ability to scratch others. Diamond conquers them all, being able to scratch any material.

In the eye of the beholder

Dear **HIW,**

To my eyes all wildlife is beautiful. Why is it that by comparison I often see humans that just display ugliness, say, as they get older?

Stephen Conn

It might be because humans are the most common species that you see in daily life. As you have become so used to seeing the human form, the sight of one is less likely to excite you in the same way as spotting a glimpse of a fox or watching a horse run through a field.

As for age being a factor, most people are programmed to find babies cuter. We need to want to protect and nurture any children that we might have, and scientists believe that this affection may be working to change our perception of the young of any species.

© Getty

What's happening on... social media?

This month on Instagram we asked you: what animal fascinates you the most?

@francodetejada
Mantis shrimp, because it's an awesome animal with lots of cool features

@kevinmansley
Tigers. They seem very reserved and shy animals, but at the same time are powerful predators.

@cathode149
Hooded vultures... their effect on the environment and their decline fascinates me.

@sammy.glanfield
Glass frog because of their extraordinary underside.

@scimaxfacts
The naked mole rat because it is so unique and unusual!

@jack_macneilly
Naked mole rat because it is immune from cancer

NEXT ISSUE...

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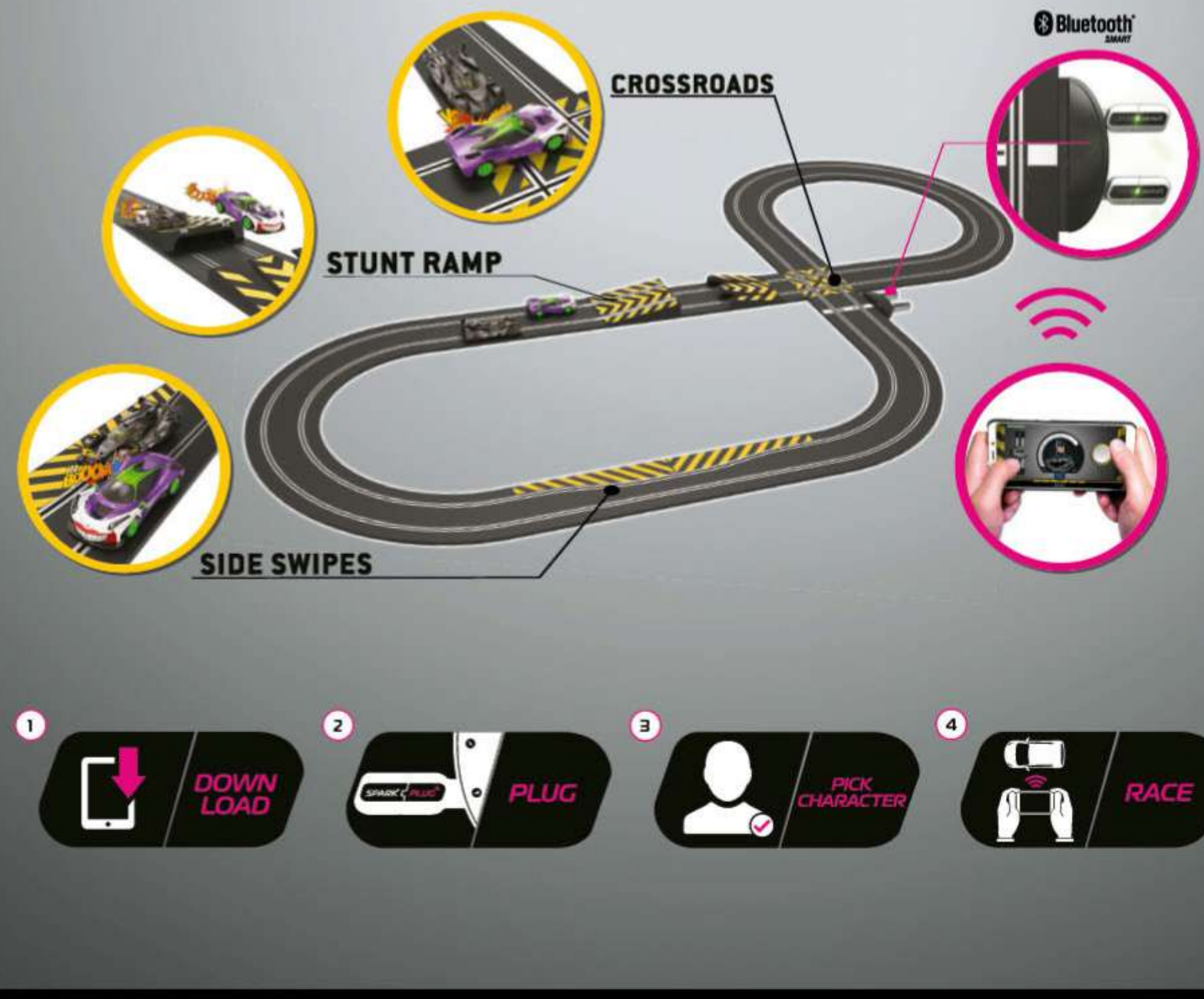

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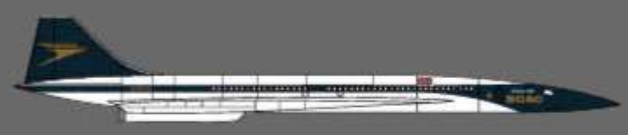

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